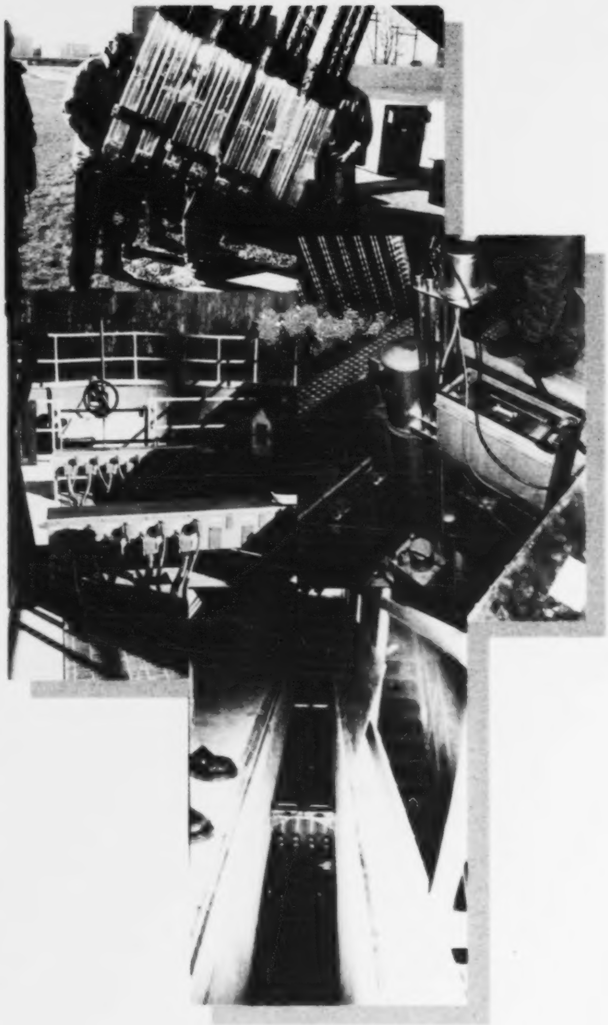

Ultraviolet Disinfection Technology for Municipal Wastewater Treatment Plant Applications in Canada

Prepared for

The Corporation of the City of Windsor
In Partnership with
Government of Canada, Ontario Ministry of the Environment and The Federation of Canadian Municipalities

October 2003

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Ultraviolet Disinfection Technology for Municipal Wastewater Treatment Plant Applications in Canada

Final Report

Prepared for

The Corporation of the City of Windsor
In Partnership with
Government of Canada, Ontario Ministry
of the Environment and
The Federation of Canadian Municipalities

Prepared by

Hydromantis, Inc. and Stantec Consulting Ltd.

October 2003

Disclaimer

This report was prepared for The Corporation of the City of Windsor in partnership with the Government of Canada, Ontario Ministry of the Environment, and the Federation of Canadian Municipalities. The views and ideas expressed in this report are those of the authors and do not necessarily reflect the views and policies of the aforementioned governments and agencies, nor does the mention of vendors, trade names and commercial products constitute an endorsement or recommendation for use.

The preliminary cost estimations and associated sizes of alternative process options developed for the generic applications described in this report are not intended to be considered as applicable to any particular site that is considering new ultraviolet (UV) disinfection facilities or upgrades.

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Appendices

Appendix A – Manufacturers' Summary Sheets
Appendix B – Site Visit Summary and Report

List of Abbreviations

Abbrev.	Description
ABB	Asea Brown Boveri
ACS	Automatic Cleaning System
ADWF	Average Dry Weather Flow
AOC	Areas of Concern
ASP	Activated Sludge Processes
ATSI	Aqua Technical Sales Inc.
BAF	Biological Aerated Filter
BCA	Clearwater Group, British Columbia
$Ca(OCl)_2$	Calcium Hypochlorite
CEPA	*Canadian Environmental Protection Act*
CSO	Combined Sewer Overflow
DBP	Disinfection Byproduct
DCS	Distributed Control System
DNA	Deoxyribonucleic Acid
E. coli	*Escherichia coli*
ENR	Engineering News-Record
GLSF	Great Lakes Sustainability Fund
HCl	Hydrochloric Acid
HO	High Output
HOCl	Hypochlorous Acid
HVAC	Heating Ventilation and Air Conditioning
IFAS	Integrated Fixed Film Activated Sludge
LP/HI	Low Pressure/High Intensity
LP/LI	Low Pressure/Low Intensity
LPX	Low Pressure, Extra Output
LRPCP	Little River Pollution Control Plant
LRWRP	Lou Romano Water Reclamation Plant
MCC	Motor Control Centre
MGD	Million gallons per day
mg/L	Milligrams Per Litre
MLD	Million Litres per Day
MOE	Ministry of the Environment
MP Lamps	Medium Pressure Lamps
MP/HI	Medium Pressure/High Intensity
MPN	Most Probable Number
$mW{\cdot}s/cm^2$	Milliwatt second per square centimeter
NaOCl	Sodium Hypochlorite

Abbrev.	Description
NEMA	National Electrical Manufacturers Association (numbers beside acronym refer to the enclosure rating, e.g. NEMA 12)
nm	nanometer
O & M	Operating and Maintenance
O_3	Ozone Gas
PDC	Power Distribution Center
PLC	Programmable Logic Controller
PSS	Point Source Summation
PWWF	Peak Wet Weather Flow
R&D Facility	Research and Development Facility
RNA	Ribonucleic Acid
SCADA	Supervisory Control and Data Acquisition
SCC	System Control Center
SLR	Single Lamp Reactor
SS	Suspended Solids
SVSY	Services Systems International Ltd.
TF/SC	Trickling Filter/Solids Contact
torr	Torr (Millimetre of Mercury)
TSS	Total Suspended Solids
UPS	Uninterruptible Power Supply
US	United States
UV	Ultraviolet
UVST	UV Systems Technology Inc.
UVT	Ultraviolet Transmittance; refers to unfiltered transmittance unless otherwise noted
VFD	Variable Frequency Drives
VLS	Vertical Lamp System
WEF	Water Environment Federation
WEFTEC	Water Environment Federation Technical Exhibition and Conference
WERF	Water Environment Research Foundation
WWTP	Wastewater Treatment Plant

Executive Summary

This manual reviews ultraviolet disinfection technology and advancements for application in disinfecting effluents from municipal wastewater treatment plants (WWTPs). The report is intended to serve as an information source and decision-support tool to assist municipal engineers and managers at WWTPs. It discusses the commercially available UV technologies and respective manufacturers, and the criteria and issues involved in the application of UV disinfection. This can include new installations or retrofitting of existing UV equipment.

Based on a review of recent relevant literature sources and input from UV system manufacturers, this manual provides detailed information on UV technology use in North America. The report consolidates key planning, design, operation and cost information for UV disinfection installations at WWTPs. The manual concentrates on UV disinfection of secondary activated sludge wastewater treatment plant effluents. However, consideration is also given to applications involving UV disinfection of effluents from other municipal wastewater treatment process types.

A complete review of UV technology and equipment is provided. The review shows that UV irradiation is a viable, economical option for disinfection of secondary wastewater effluents. The technology has been available since the early 1920's but has only been applied commercially for full-scale wastewater applications since around 1980. The principal parameter controlling the process is the UV dose, which is a function of UV intensity and exposure time. Factors impacting UV performance include UV light intensity, exposure time and wastewater characteristics. Three major lamp technologies are available for UV disinfection of wastewater effluents, including low pressure/low intensity (LP/LI), low pressure/high intensity (LP/HI) and medium pressure/high intensity (MP/HI). LP/HI lamps are common to multiple manufacturers and are available for a wide range of electrical inputs. For this manual LP/HI lamps are subdivided into two categories; lamps rated less than 500 W are referred to as Level 1 lamps, and those above are referred to as Level 2 lamps.

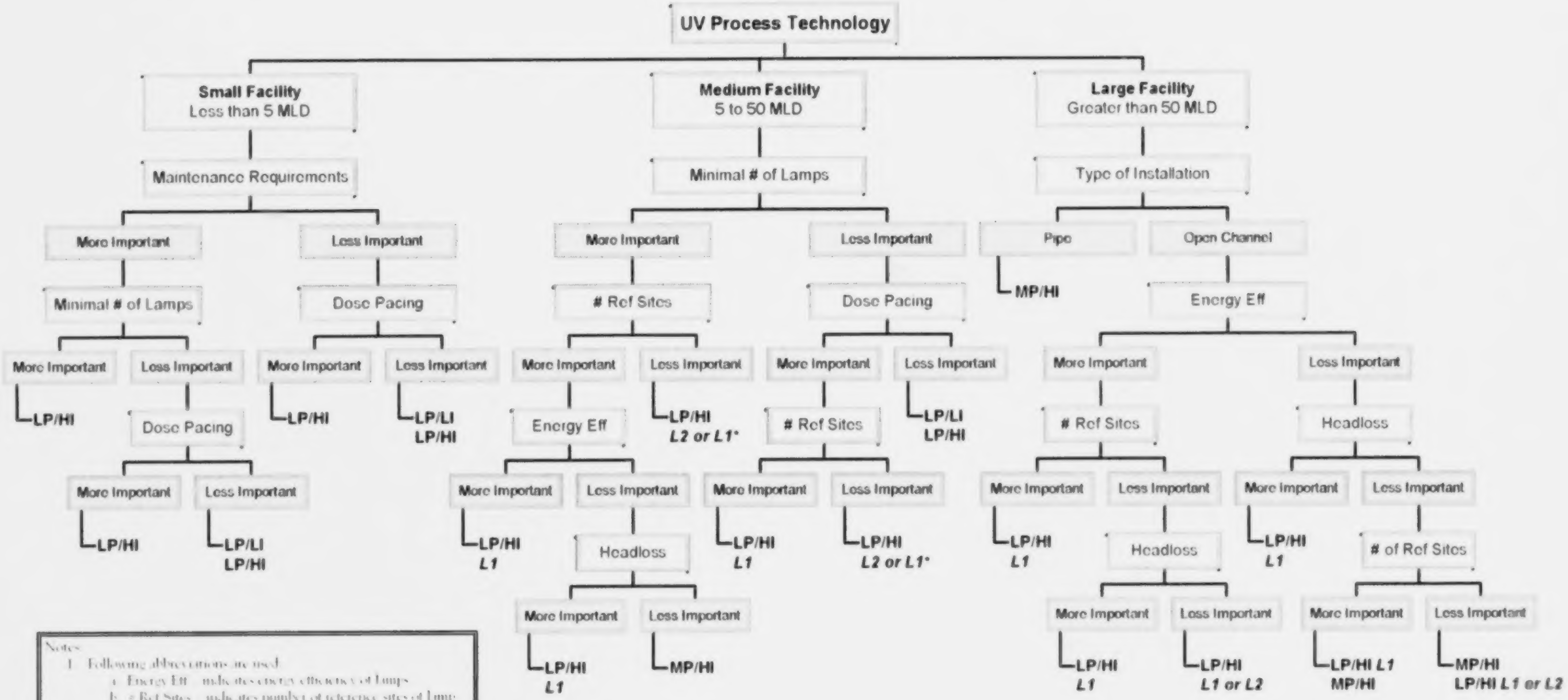
This report covers the needs for applying UV technology to various situations. Many factors need to be considered when choosing a UV system for a particular site. Issues such as site conditions, effluent characteristics, compliance requirements, plant hydraulics and layout, and others need to be considered for a particular site. A detailed list of screening criteria has been provided in **Section 6.0** for review for all UV installations. A preliminary decision-tree was developed to assist in suggesting an appropriate UV technology for a given site, which together with a list of various factors and considerations can lead to the selection of an appropriate process. **Figure ES1.1** shows the preliminary decision-tree. Additional criteria items are also provided for consideration by the manual user. It should be cautioned that the decision tree or selection tool follows an arbitrary approach and only identifies a format or process to use to make an initial screening of potential issues and the impact these may have on UV selection. The user can use this approach and their own criteria and weighting to make a decision tree or selection tool for their own application. Two example applications for the preliminary decision-tree procedure with a discussion on additional criteria are provided in **Section 6.4**. These examples are for a new installation and a potential retrofit application.

It must be emphasized that the preliminary decision tree is intended for preliminary process screening and that the actual selection of an appropriate technology and design will be site specific. The suggested category of lamp technology identified as being most appropriate based on process screening is not intended to be exclusive. The suggestions should not be construed as ruling out consideration of the other UV process alternatives. The list and discussion of factors and considerations provided in this manual should be reviewed together with the use of the sample decision tree in identifying appropriate solutions.

Generic pricing for a range of plant sizes from small to large and with poor (i.e., average UV transmittance of 50%) or good (i.e., average UV transmittance of 70%) secondary effluent was obtained for comparison. Issues such as the impact of effluent quality and transmittance, lamp life, plant size and installed power requirements are discussed for each lamp type.

This manual's purpose is to provide information and guidance to communities investigating UV technology for application at their wastewater plants. Criteria and tools provided are to assist in the initial evaluation of the issues and the preliminary selection of UV technologies. At this point additional engineering consultation and manufacturer input should be obtained to develop the best system and solution for a particular installation.

Figure ES1.1 **Example Decision Tree for Preliminary Selection of UV Technologies for Various Applications**


UV Process Technology
Small Facility
Less than 5 MLD
Medium Facility
5 to 50 MLD
Large Facility
Greater than 50 MLD
Maintenance Requirements
Minimal # of Lamps
Type of Installation
More Important
Less Important
Minimal # of Lamps
Dose Pacing
More Important
Less Important
LP/HI
Dose Pacing
More Important
Less Important
LP/HI
LP/LI
LP/HI
More Important
Less Important
LP/HI
LP/LI
LP/HI
More Important
Less Important
# Ref Sites
Dose Pacing
More Important
Less Important
Energy Eff
LP/HI
L2 or L1*
More Important
Less Important
LP/HI
L1
Headloss
More Important
Less Important
LP/HI
L1
MP/HI
More Important
Less Important
# Ref Sites
LP/LI
LP/HI
More Important
Less Important
LP/HI
L1
LP/HI
L2 or L1*
Pipe
Open Channel
MP/HI
Energy Eff
More Important
Less Important
# Ref Sites
Headloss
More Important
Less Important
LP/HI
L1
Headloss
More Important
Less Important
LP/HI
L1
LP/HI
L1 or L2
More Important
Less Important
LP/HI
L1
# of Ref Sites
More Important
Less Important
LP/HI L1
MP/HI
MP/HI
LP/HI L1 or L2

Notes:

1. Following abbreviations are used:
    a. Energy Eff = indicates energy efficiency of lamps
    b. # Ref Sites = indicates number of reference sites of lamp technology
    c. Headloss = headloss requirements
    d. Dose pacing = modulating the power to the lamps
2. Lamp abbreviations are:
    a. LP/LI = low pressure/low intensity
    b. LP/HI = low pressure/high intensity
    c. MP/HI = medium pressure/high intensity
3. L1 and L2 indicate wattage of lamps, L1 (Level 1) is less than 500 W per lamp, L2 (Level 2) is greater than 500 W per lamp
4. Lamp orientation options are available for a number of units and should be assessed separately
5. * indicates that headloss may need to be assessed for the LP/HI L2 lamps as well

Hydromantis, Inc.
Consulting Engineers

Stantec

Project No. 332-04 E / March 13, 2003

Figure ES.1 - Example Decision Tree for Preliminary Selection of UV Technologies for Various Applications

1 Introduction

1.1 Overview

Hydromantis, Inc. in association with Stantec Consulting Ltd. was retained to conduct a Ultraviolet (UV) disinfection technology review and feasibility study for the City of Windsor, Environment Canada, the Ontario Ministry of the Environment, and the Federation of Canadian Municipalities. The project involves a thorough review of current UV disinfection technology and applications. Information gathered in this review is to be used to:

- Develop a manual for UV applications in Canada
- Assess and report on the feasibility of converting the existing UV disinfection system at the Little River Pollution Control Plant (LRPCP) to more current UV technology

This report is a manual for UV technology application for municipal wastewater treatment in Canada.

1.2 Background

Ultraviolet irradiation has been used for disinfecting secondary treated effluents throughout North America since the 1980s. Most of these applications are for suspended growth type secondary and tertiary effluents where such parameters as effluent quality (turbidity and suspended solids), transmittance and phosphorous removing chemicals used (alum versus ferric) are the main factors in UV applicability and dose requirements. Currently, many wastewater treatment facilities are utilizing UV disinfection or are considering upgrading to it.

Municipal wastewater contains a variety of pathogenic organisms of human origin. Disinfection is necessary to reduce transmission of infectious diseases when human contact is probable. Waterborne transmission of disease-causing organisms can occur through a variety of ingestion and invasion (i.e. skin contact) pathways (USEPA, 1986).

In the past, chlorine has been used almost universally for wastewater effluents. However, chlorine and its byproducts are known to have serious toxic effects on aquatic life following discharge of chlorinated effluents to surface waters. Other concerns with chlorine gas include (WERF, 1995):

- Formation of trihalomethanes and other chlorinated organics
- Increased safety issues and regulations concerning chlorine gas use, handling, and transportation

Chlorinated wastewater effluents and inorganic chloramines have recently been added to the List of Toxic Substances, Schedule 1, under the *Canadian Environmental Protection Act* (CEPA, 1999). The major quantifiable sources of these substances released to aquatic ecosystems across Canada are municipal wastewater systems. Inorganic chloramines may be formed when chlorine and residual ammonia combine in the aqueous phase. A range of options is available to the Federal government to promote a reduction in the release of these CEPA-toxic substances from municipal wastewater treatment plants (WWTPs). These include regulatory and voluntary initiatives, economic measures, environmental quality or release guidelines, codes of practice, and pollution prevention plans.

Ultraviolet disinfection has provided an attractive alternative to chlorine for wastewater effluent applications. UV technology has also developed over the recent past to address the current interest and meet the industry demand. Numerous manufacturers are available with competitive and unique processes available for any given application. This manual provides a review of the technology and the main manufacturers available, and reviews the options for consideration concerning UV disinfection.

1.3 Organization of the Manual

The format and presentation of this manual has been developed to be readily accessible to a wide audience of municipal engineers and managers. Therefore, the information is presented in a number of chapters with references throughout and information on UV manufacturers and site visits provided in the appendices.

The manual is divided into the following chapters:
Chapter 1 – Introduction: Provides background information on UV disinfection and the organization and scope of the manual.

Chapter 2 – Review of Disinfection Options: This chapter reviews the main disinfection options available for wastewater treatment plant effluent, including the advantages and disadvantages of each.

Chapter 3 – Review of UV Disinfection: This chapter presents the basis of UV disinfection and the main characteristics that dictate its performance and the components of the equipment.

Chapter 4 – Manufacturer's Review: This chapter reviews the main UV manufacturers available in North America and presents a summary of their systems.

Chapter 5 – Planning and Design Considerations for UV Disinfection Applications: This chapter outlines and discusses important considerations related to the preliminary assessment, planning, and design of UV disinfection applications.

Chapter 6 – Screening of Alternative UV Technologies: This chapter provides a preliminary process screening procedure to facilitate the identification and selection of appropriate alternatives for different wastewater disinfection applications and scenarios, taking into consideration certain key criteria.

Chapter 7 – Developing a Strategy: This chapter provides a list of the information that is required from UV manufacturers when considering the application of UV disinfection. In addition, a summary of generic design and costing information is provided based on a survey of the major UV manufacturers.

1.4 Scope of the Manual

This manual consolidates key planning, design, operation, and cost information for UV disinfection installations at municipal WWTPs in Canada. The manual is intended to provide information and guidance to municipal engineers, scientists, managers, and wastewater treatment plant operators. With the information provided in the manual, municipal staff should be able to develop a strategy to select an appropriate UV disinfection system and to prepare a submission to Council to secure funds to engage an engineering consultant.

Although the report focuses mainly on UV disinfection of secondary and tertiary wastewater treatment plant effluent, with particular emphasis on activated sludge process effluents, effluents from other treatment process types are also given consideration.

2 Review of Disinfection Options

2.1 Basis for Disinfection

Disinfection, in contrast to sterilization or complete elimination of all organisms, is the selective inactivation or destruction of pathogenic organisms. It does not destroy all of the organisms present but reduces the number of active pathogenic organisms to safe levels (WERF, 1995).

The disinfection of wastewater treatment plant effluents is important to ensure that unacceptable levels of disease-causing organisms do not contaminate the receiving water body. This is especially important if the water body is used for recreational purposes, aquaculture, or irrigating crops (WEF, 1996). If the receiving body is only used for recreational purposes, disinfection may only be required on a seasonal basis. In Canada, many WWTPs do not disinfect their effluents during winter months. Further, many WWTPs in Canada do not disinfect at all since their receiving water uses do not require pathogen reduction for the protection of public or aquatic health.

The pathogenic microorganisms of principal concern in wastewater effluent are bacteria, viruses, and protozoa (Darby *et al.*, 1995). Indicator organisms are used to specify the presence of these pathogens. Coliform bacteria are commonly used as indicators in wastewater applications because they are present in high concentrations and show similar disinfectant sensitivity and inactivation rates as the majority of pathogenic organisms except for some protozoa and viruses. Disinfection standards for wastewater effluent are commonly expressed in terms of coliform bacteria concentrations (i.e., most probable number (MPN) per 100 mL). Coliform bacteria include a number of genera and species of bacteria that have common biochemical and morphological attributes. The microorganism *Escherichia coli* (*E. coli*), found in the feces of warm-blooded animals, is one of many coliform organisms (Metcalf & Eddy, 2003). Tests have been developed that distinguish among total coliforms, fecal coliforms, and *E. coli*.

2.2 Disinfection Options

Disinfectants for treating WWTP plant effluent fall under two main categories: oxidizing chemicals and ultraviolet light. Oxidizing chemicals include chlorine, bromine, ozone, potassium permanganate, hydrogen peroxide, chlorine dioxide, chloramines, and bromine chloride. For wastewater disinfection, the most widely used disinfectants are chlorine, ozone, and ultraviolet light (WEF, 1996). These disinfection options are discussed in detail below.

2.2.1 Chlorination

Chlorine is normally added to wastewater as gaseous chlorine or a hypochlorite compound. Chlorine dioxide can also be used, although its cost is often prohibitive (WEF, 1996).

When chlorine gas is added to wastewater it undergoes the following chemical reaction:

$$Cl_2(g) + H_2O \text{ n } HOCl + HCl$$

The hydrochloric acid (HCl) dissociates almost completely to H^+ and Cl^-. Hypochlorous acid (HOCl) is a weak acid that partially dissociates according to the following reaction:

$$HOCl \ \mathrm{n} \ H^+ + OCl^-$$

The equilibrium point of this reaction depends on the pH of the wastewater. At pH levels below 6.5 no dissociation occurs, which is preferable because $HOCl$ has a stronger germicidal effect than OCl (USEPA, 1999a).

The most commonly used hypochlorites for wastewater disinfection are sodium hypochlorite (NaOCl) in liquid form (liquid bleach) or calcium hypochlorite ($Ca(OCl)_2$) in solid form (powder bleach) (WEF, 1996). When added to wastewater, the following chemical reactions occur:

$$NaOCl + H_2O \ \mathrm{n} \ NaOH + HOCl$$

$$Ca(OCl)_2 + 2H_2O \ \mathrm{n} \ Ca(OH)_2 + 2HOCl$$

Chlorine is effective at inactivating bacteria and viruses. It has been found to affect reproduction and metabolism, cause mutations, and ultimately cause death in these microorganisms (WEF, 1996). Chlorine is not as effective at treating wastewater infected with protozoa such as *Cryptosporidium*, leading to the need for filtration (WEF, 1996).

Gaseous chlorine is typically added to wastewater using a diffuser upstream from a serpentine contact chamber. Proper mixing of the chlorine and wastewater before entry into the contact chamber is important for proper disinfection.

The disinfection effect of chlorine depends on both the contact time and the dosage applied. Typical contact times and dosages for secondary wastewater plant effluents are 30 minutes and 2 to 8 mg/L, respectively (WEF, 1996). Depending on regulatory requirements, the contact time can range from 30 to 120 minutes (Metcalf & Eddy, 2003). The chlorine dose remaining after any reactions with reducing agents in the wastewater is termed the residual. The residual is available for disinfection and remains in the wastewater after treatment. This is useful for drinking water treatment because it ensures that the water is not re-contaminated, but can be problematic in wastewater applications because of possible toxic effects on aquatic life. Dechlorination is normally required when the discharge is released into surface water bodies. Chlorine residuals are often removed using sulphur dioxide or sulfite salts (WEF, 1996).

2.2.2 Ozonation

Ozone gas (O_3) is a chemical disinfectant used as an alternative to chlorine. It is highly effective on bacteria, viruses, and protozoa (WEF, 1996). Ozone disinfection is thought to occur through oxidation reactions between ozone, or the hydroxyl radicals that it decomposes into, and the organic compounds that comprise the microorganisms (USEPA, 1999a). In the case of bacteria, oxidation reactions damage the cell wall and lead to lysis of the cell (WEF, 1996).

There are a number of different systems available for contacting wastewater with ozone including fine-bubble diffusers, turbine mixers, injectors and static mixers, and spray chambers. Fine-bubble diffusers are the most commonly used ozone contacting systems (WEF, 1996). In these systems, a serpentine contact chamber is used with either cocurrent or countercurrent diffusion of the ozone gas.

The ozone gas used in ozone contact systems is manufactured on-site by passing an alternating current across a dielectric discharge gap filled with oxygen-rich gas (USEPA, 1999a). The oxygen-rich gas may be ambient air or high-purity liquid or gaseous oxygen. The ozone remaining in the off-gas must be converted back to oxygen before release because of its toxic health affects. This is done by heating the off-gas or contacting it with a metal catalyst (WEF, 1996).

The disinfection effect of ozone depends on both the contact time and the dosage delivered. Contact times for ozone disinfection are shorter than for chlorine disinfection with typical values of between 10 to 30 minutes (WEF, 1996; USEPA, 1999c).

Residual ozone in the treated wastewater has been shown to be toxic to aquatic life. This is not a major concern because the residual ozone disappears rapidly due to oxidation reactions with the organic and inorganic materials in the water.

2.2.3 Ultraviolet Irradiation

Ultraviolet light is electromagnetic energy with wavelengths ranging from 100 to 400 nm. This energy spectrum lies between X-rays and visible light. The UV energy spectrum can be divided into four ranges:

- Vacuum UV (100 – 200 nm)
- UV-C (200 – 280 nm)
- UV-B (280 – 315 nm)
- UV-A (315 – 400 nm)

UV light between 200 nm and 300 nm has a germicidal effect (Jeyanayagam *et al.*, 2000). The optimum germicidal UV range is between 250 and 270 nm (Darby *et al.*, 1995) with the optimum wavelength being approximately 265 nm (Meulemans, 1987).

Ultraviolet light is produced in wastewater disinfection systems by mercury vapour lamps. Three main types of lamps are available that are characterized by both their operating pressure and their output level: low pressure/low intensity lamps (LP/LI), low pressure/high intensity lamps (LP/HI), and medium pressure/high intensity lamps (MP/HI).

Low pressure lamps produce essentially monochromatic radiation at 253.7 nm, while medium pressure lamps produce polychromatic radiation. This is discussed in more detail in **Section 3.3.1**.

UV light, in relatively low doses, is effective on bacteria, viruses, and protozoa. UV light inactivates microorganisms by causing photochemical damage to their nucleic acids (DNA and RNA) making them unable to reproduce.

Ultraviolet disinfection systems are available in both open channel and closed chamber reactor configurations. In these systems, the wastewater flows through an array of lamps that can be arranged either horizontally or vertically in the reaction channel or chamber.

The effectiveness of UV disinfection depends on both the contact time and the intensity of the UV light. Contact times for UV disinfection of secondary wastewater effluent using low pressure lamps may range from 7 to 30 seconds (Darby *et al.*, 1995; USEPA, 1999b). The retention time is much less (i.e., typically less than 1 second) with medium pressure UV systems. More detail on UV irradiation including the equipment used is given in **Chapter 3**.

2.3 Advantages and Disadvantages of the Different Disinfection Methods

The advantages and disadvantages of chlorination, ozonation, and ultraviolet irradiation are summarized in **Table 2-1**. As shown, UV disinfection has many advantages over chlorine. UV disinfection is a physical process rather than a chemical disinfectant, and is safer, requires shorter contact times, and does not have problems with residual toxicity.

Chlorine gas is extremely volatile and toxic. A number of safety precautions are required for transportation and storage. In comparison, UV light and ozone are created as needed, although ozone gases must be disposed of prior to release into the atmosphere. UV light is not a safety concern unless treatment plant workers are directly exposed at close range.

UV disinfection requires much shorter contact times than with chlorine and ozone. As mentioned in **Section 2.2**, contact times for UV disinfection systems using LP/LI lamps range from approximately 7 to 30 seconds compared with about 30 minutes for chlorine disinfection and about 10 minutes for ozonation.

A major disadvantage of chlorine is that it is toxic to aquatic life and forms disinfection byproducts (DBPs) that are suspected carcinogens. UV light does alter some chemical compounds, but is thought to have a negligible environmental impact on the receiving water body (Darby *et al.*, 1995).

A major disadvantage of UV disinfection relative to chlorination is its cost. Chlorine disinfection has traditionally been more cost effective than UV in terms of capital and operating and maintenance (O & M) costs (Darby *et al.*, 1995). This is likely to change in the future as UV disinfection technology improves and becomes more cost competitive. Furthermore, costs of UV disinfection are competitive when chlorination-dechlorination is used and fire codes are met (WERF, 1995; USEPA, 1999b). Current fire codes require costly safety precautions for the storage, shipping, and handling of chlorine.

A potential limitation is that turbidity and suspended solids in the wastewater can render UV disinfection ineffective. In particular, UV disinfection with low-pressure lamps is not as effective for secondary treated effluent with TSS levels consistently greater than 30 mg/L (USEPA, 1999b). The latter would not be a feasible application of the low pressure UV lamp technology.

Table 2-1 Main Advantages and Disadvantages of the Different Wastewater Disinfection Methods (Adapted in part from Darby *et al.*, 1995, Metcalf & Eddy, 2003)

Advantages	Disadvantages
Chlorine Disinfection 1. Well-established technology 2. Effective disinfectant for bacteria and viruses 3. Relatively low cost; however, if chlorination/dechlorination utilized, capital costs are comparable to other technologies 4. Chlorine residual can be monitored and maintained	1. Residual chlorine is toxic to aquatic life; dechlorination may be required 2. Chlorinated wastewater effluents and inorganic chloramines are CEPA toxic 3. Safety concerns with storage and handling of chlorine chemicals 4. Volatile organic compounds released from contact chambers 5. Not effective at treating protozoa at low chlorine doses normally used for coliform bacteria 6. Dependent on pH of wastewater 7. Chlorinated hydrocarbons (possible cancer risk in humans) may be formed as DBPs and released 8. Chlorine is highly corrosive 9. Relatively long contact time
Ozone Disinfection 1. Effective disinfectant for bacteria, viruses, and protozoa 2. Shorter treatment times than chlorine (10 to 30 minutes) 3. Less dependent on pH than chlorine 4. Improves quality of wastewater in terms of colour, odour, turbidity, and dissolved oxygen 5. Residual ozone is toxic but the residual disappears quickly in the receiving stream.	1. Relatively expensive and complex 2. Ozone must be generated and disposed of on-site 3. Ozone is highly corrosive and toxic 4. Safety concerns 5. Energy intensive 6. No immediate measure of efficacy 7. No residual effect 8. Formation of DBPs 9. Highly O&M sensitive
UV Disinfection 1. Effective disinfectant for bacteria, viruses, and protozoa 2. Safer than chlorine or ozone 3. No residual toxicity 4. No DBPs formation at typical doses 5. Shorter treatment times than chlorine or ozone (7 to 30 seconds) 6. Requires less space than chlorine or ozone contactors	1. Moderately high cost 2. Plant personnel should avoid exposure to UV radiation when performing maintenance duties 3. UV disinfection efficiency affected by wastewater quality 4. No immediate measure of efficacy 5. Energy intensive 6. No residual effect

Ozone also has advantages over chlorine but is not as safe as UV and is more expensive. Ozone also has the disadvantage that it must be manufactured and disposed of on-site which is costly.

2.4 The Future of Disinfection

Traditionally chlorination has been the most commonly used method for wastewater disinfection. Ozonation and UV disinfection are emerging technologies developed as alternatives to chlorine. Because of its advantages over both chlorination and ozonation, UV disinfection is becoming increasingly prevalent. In the future, it is expected that older chlorine disinfection facilities will continue to be replaced with UV disinfection and that most new installations will use UV disinfection technology.

The recent declaration of chlorinated wastewater effluents and inorganic chloramines as CEPA toxic substances will require many existing municipal wastewater plants in Canada (i.e., those that employ chlorination) to undertake pollution prevention plans or implement other upgrade measures (**Section 1.2**). The application of UV disinfection technology represents a particularly suitable alternative to address these forthcoming requirements.

3 Review of UV Disinfection

The following material focuses on UV disinfection as it applies to the treatment of secondary wastewater effluent. The basics of UV disinfection are discussed along with factors that can influence the effectiveness of a UV disinfection system.

3.1 Effect of UV Radiation on Microorganisms

3.1.1 UV Inactivation Mechanism

UV light in the optimum germicidal range (250 to 270 nm) inactivates microorganisms by causing photochemical damage to their genetic material (DNA and RNA). When the genetic material of a cell is damaged it is unable to reproduce and is inactivated. The damage is caused by the formation of double bonds (dimerization) between the pyrimidine molecules in the DNA and RNA (Darby *et al.*, 1995). Once these bonds are formed, the helical structure of the nucleic acids becomes distorted and their replication becomes difficult. This is shown in **Figure 3.1**.

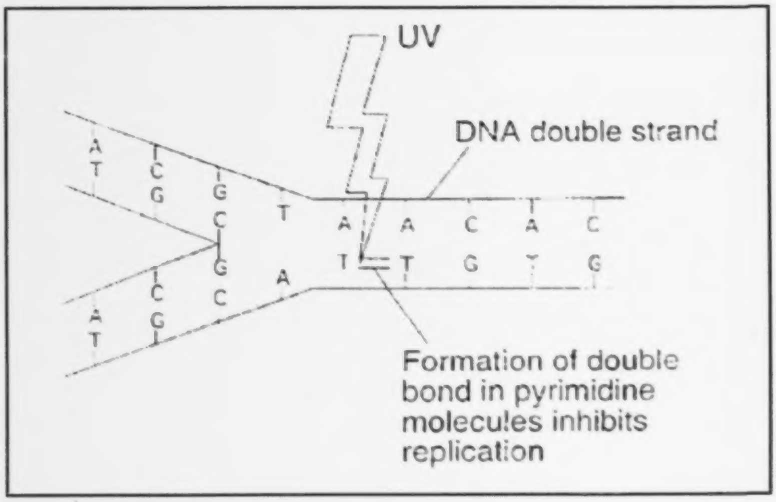

UV
DNA double strand
A
T
C
G
G
C
T
A
A
T
A
T
C
G
A
T
C
G
G
C
C
G
A
T
Formation of double bond in pyrimidine molecules inhibits replication

Figure 3.1 Germicidal Effect of UV Radiation (adapted from USEPA, 1999a)

3.1.2 Dose of UV Light Delivered

The disinfection effect of UV light depends on the dose delivered to the microorganisms. The UV dosage is defined as:

$$D = I \times t$$

Where:

D = UV dose (mW·s/cm^2)

I = intensity of the UV light (mW/cm^2)

t = exposure time (seconds)

It is found that for a given light intensity, a constant fraction of the living microorganism population is inactivated with each increment in time (USEPA, 1999a).

As expected the degree of inactivation increases with increasing dose. The relationship between applied UV dose and the resulting inactivation of a microorganism can be determined using a collimated beam test. In this test, the organism is placed in solution in a Petri dish and exposed to a beam of UV light with known intensity for a defined and measured period of time. The UV dose delivered in the test can be adjusted by varying the time of the experiment and the intensity of the UV light. A dose-response relationship can be developed by measuring the microbial inactivation achieved at different applied UV dose levels. Typical dose-response results for wastewater effluents with different TSS concentrations are shown in **Figure 3.2**. In this figure MPN stands for most probable number of coliform bacteria. The total coliform concentration is plotted using a logarithmic scale.

The UV dose delivered by a continuous-flow UV disinfection system can be estimated using two different methods. In the bioassay method, the dose-response results from a collimated beam test are used to back-calculate the dose delivered by a continuous-flow UV disinfection test system that is a scaled representation of a full-scale unit. This is done by seeding the test system with the organism of interest and measuring the resulting inactivation. The dose delivered by the test system can then be calculated using the dose-response curve and the measured inactivation and these results can then be translated to full-scale. This procedure should be repeated over a range of flow conditions. There is some controversy associated with using the dose-response results in this way because the intensities used in a collimated beam test are relatively low compared to those used in a field-scale UV disinfection system (Darby *et al.*, 1995).

Alternatively, the dose delivered by a UV disinfection system can be estimated using a mathematical approach. This involves calculating the average UV intensity in the system and multiplying this by the estimated exposure time within the system. The exposure time is a function of the flow rate and the reactor configuration and is often calculated assuming plug-flow conditions. Plug-flow conditions occur in a channel when the flow is highly turbulent in the radial direction so that fluid particles pass through the channel and are discharged in the same sequence in which they enter with no short-circuiting. The fluid velocity is constant across the width of the channel and there is minimal mixing along the length of the channel.

The average UV light intensity found within a UV disinfection system can be estimated using the point source summation (PSS) method developed by Jacob and Dranoff (1970). In the PSS method, the UV lamps within a UV reactor are treated as a series of point light sources that radiate light in all directions. The UV intensity at any point in the UV reactor is calculated as the sum of all the intensities reaching the point from all the point sources. The transmittance of the wastewater must be taken into account when doing this calculation. The transmittance is the ability of the wastewater to transmit UV light, expressed as a percentage. It is typically measured using a spectrophotometer (Darby *et al.*, 1995). In addition the effects of chemical compounds and particles in the wastewater

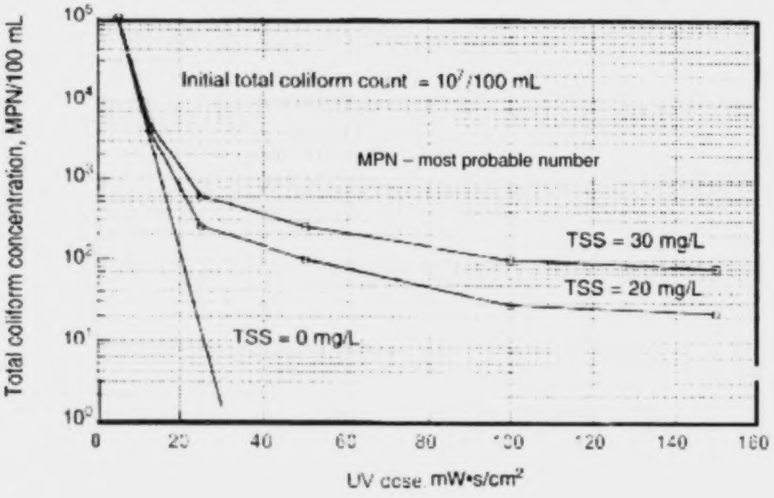


Figure 3.2 **Typical Dose Response Curves for Wastewater Effluents Containing Different TSS Concentrations (Tchobanoglous *et al.*, 1999)**

must be taken into account, because they can reduce the amount of UV light that reaches the microorganisms.

Although both methods of estimating the dose delivered are used, the bioassay approach is preferred because it measures the actual inactivation achieved by a real reactor (Lawryshyn and Chiu, 2002). The PSS method only provides an estimate of the average dose delivered, which can be the same for different dose distributions (WEF, 1996). Despite this, the PSS method is preferred by some practitioners because not all bioassay protocols are uniform, which can make it difficult to compare test results from different sources. A problem with both methods is that they estimate a single number that represents the dose delivered (WEF, 1996). In reality, UV disinfection systems deliver a distribution of doses.

3.1.3 Sensitivity of Pathogens to UV Light

Although the dose required for inactivation varies with the type of microorganism, most pathogens can be inactivated with relatively low doses of UV light. Coliform bacteria are commonly used as indicators of other pathogens in wastewater applications. Typically a UV dose in the range of 10 to 40 mW·s/cm^2 achieves a 5 to 6 log-unit reduction in the total number of active coliform organisms (Tchobanoglous *et al.*, 1999), as shown in **Figure 3.2**. In this figure the initial coliform count is 10^7/100 mL. At a total suspended solids level of 20 mg/L a dose of 40 mW·s/cm^2 reduces the coliform count to approximately 100/100 mL, which is a reduction of 5 intervals on a logarithmic scale.

Recent research (Craik *et al.*, 2000; Craik *et al.*, 2001) has shown that both *Cryptosporidium* and *Giardia* can be inactivated with low doses of UV light. Previously, it was thought that high doses of

UV light were required to inactivate *Cryptosporidium* and *Giardia* but this conclusion was based on *in vitro* laboratory tests and not on animal infectivity tests. Craik *et al.* (2001) demonstrated a 3 log-unit inactivation of *Cryptosporidium parvum* oocysts at UV doses greater than 25 mW·s/cm^2, while Bukhari *et al.* (1999) demonstrated a greater than 4 log-unit inactivation at doses as low as 41 mW·s/cm^2.

Viruses can vary substantially in their resistance to UV light. Thompson *et al.* (2000) found that doses less than 40 mW·s/cm^2 achieved a 4 log-unit inactivation in polio virus type I but that a dose of 183 mW·s/cm^2 was required to achieve a 4 log-unit inactivation in wastewater isolated adenovirus.

3.1.4 Repair of Microorganisms

Some microorganisms are capable of repairing the damage to their nucleic acids using photoreactivation or dark repair. Photoreactivation is thought to be a two-step process that involves a photoreactivating enzyme (Lindenhauer and Darby, 1994). In the first step an enzyme-dimer complex is formed without the aid of light. In the second step light energy is used to catalyze the monomerization of the dimer and the release of the reactivating enzyme.

Dark repair occurs in the absence of light and is thought to be a multi-enzymatic process (USEPA, 1986). Two enzymes are used to release the dimer from the DNA strand and then a replicating DNA enzyme is used to repair the gap in the DNA strand.

The degree of photoreactivation in laboratory studies has been found to be related to the UV dose. Lindenhauer and Darby (1994) studied photoreactivation of total coliform in UV disinfected secondary wastewater effluent and found that the extent of reactivation decreases with increasing UV dose. Specifically, an inverse relationship was found to exist between average UV dose and the degree of photoreactivation.

Although photoreactivation of microorganisms has been observed in the laboratory, it has not been shown to occur in receiving streams. Whitby and Palmateer (1993) detected photoreactivation of fecal coliform and *E. coli* in glass bottles but not in the receiving stream. It should also be noted that no significant repair is found to occur in organisms that pose a significant health risk such as fecal streptococci (Lazarova *et al.*, 1999).

3.2 Factors Affecting UV Disinfection Performance

The effectiveness of a UV disinfection system is determined by the intensity of the UV light, the exposure time, and the wastewater characteristics (Darby *et al.*, 1993). The intensity and the exposure time are important because they determine the dose delivered. The wastewater characteristics are important because they can diminish the intensity of the light that actually reaches the microorganisms.

3.2.1 UV Light Intensity

The intensity of the UV light delivered by a UV system depends on the lamp characteristic (including power output and lamp aging), the reactor geometry (including the orientation of the lamps), and the degree of fouling that occurs on the lamp sleeves. Lamp characteristics and reactor geometry are discussed in detail in **Section 3.3**. Lamp fouling is discussed in **Section 3.2.3.3**.

3.2.2 Exposure Time

The exposure time depends on the wastewater flow rate and the hydraulic properties of the UV reactor. The reactor should be designed to encourage plug-flow conditions. Radial turbulence is important because it ensures adequate mixing which minimizes the effects of short-circuiting and particle shading (Darby *et al.*, 1995). The issue of reactor hydraulics will be discussed in more detail in **Section 3.3.4**.

3.2.3 Wastewater Characteristics

The important wastewater parameters to consider are given below:

- UV transmittance (UVT) of the wastewater
- Suspended solids concentration
- Concentration of constituents that can foul the UV lamps

The initial density of the indicator bacteria may also be an important parameter. The USEPA UV process design model (USEPA, 1986) takes into account the initial bacterial density. In contrast, the initial concentration of microorganisms was not found to be an important parameter in a UV disinfection model developed by Darby *et al.* (1995).

3.2.3.1 Effect of Wastewater Transmittance

As mentioned earlier, transmittance is the ability of wastewater to transmit UV light. As the transmittance drops the amount of UV light reaching the microorganisms also drops. Transmittance is affected by materials that can absorb or scatter UV radiation such as organic and inorganic compounds and suspended solids. This relationship is not considered to be linear.

Iron is considered to be the most important inorganic compound in terms of its absorbance of UV light. It has a high absorbency of UV light in the germicidal range and can also adsorb onto suspended solids and bacterial clumps which can prevent UV light from penetrating and reaching embedded microorganisms (Darby *et al.*, 1995).

Organic substances that can significantly absorb UV light include organic dyes and colouring agents, humic substances (decayed animal or vegetable matter), and compounds with five or six member conjugated rings such as benzene, toluene, or phenol (Darby *et al.*, 1995).

3.2.3.2 Effect of Suspended Solids

Suspended solids can reduce the effectiveness of a UV system in the following ways (Darby *et al.*, 1995):

- Particles can shade microorganisms from UV light

- Particles can scatter and absorb UV light reducing the UV light that reaches microorganisms
- Bacteria can be embedded in large particles which may shield them from exposure to the UV light

These mechanisms are shown in **Figure 3.3**.

Particle shading should not be a major concern if plug-flow conditions exist in the reactor. Scattering is also not a major concern but it does decrease the average UV intensity in the reactor because the light has to travel further until it reaches the target organism (Darby *et al.*, 1995).

The embedding of microorganisms in large particles is a major concern. It has been shown that particles larger than a certain critical size can shield embedded microorganisms from UV light (Emerick *et al.*, 2000). As a result, the suspended solids concentration has an important impact on the effectiveness of UV disinfection. As the total suspended solids concentration increases, the UV effectiveness decreases. The size of particulate matter is also a factor that may influence the effectiveness of UV disinfection.

3.2.3.3 Effect of Substances that Can Foul the Lamps

Lamp fouling occurs due to the accumulation of inorganic, organic, and biological solids on the quartz sleeves that surround the lamps. This reduces the intensity of the UV light that reaches the microorganisms.

Inorganic fouling is usually due to the presence of metal ions such as iron, calcium, or magnesium in the wastewater. These metals form carbonates and sulfates that have decreased solubility at higher temperatures and tend to form on the quartz sleeves due to the heat of the lamps (Gehr *et al.*, 2000). High iron concentrations are often due to the addition of ferric chloride to the wastewater for the purposes of phosphorus removal. High levels of calcium and magnesium are found in hard water. Unfortunately, there is no general rule for determining when water hardness becomes a problem. The pH of the wastewater is an important parameter with respect to scaling because it affects the solubility of the scaling material.

Organic fouling of lamp sleeves can involve substances such as oil, grease, and suspended solids (Gehr *et al.*, 2000). Biological fouling involves the formation of a biofilm. This can be a problem if the water remains in the system when it is not operating (Gehr *et al.*, 2000). In addition, algal growth within the UV system can be a problem if the system is exposed to sunlight. Clumps of algae can wrap around the lamps and decrease the amount of UV light that reaches the microorganisms.

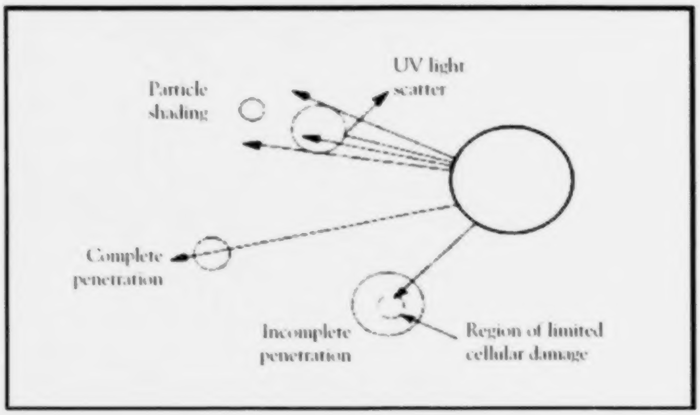


Figure 3.3 **The Effect of Suspended Solids on UV Disinfection (Snider *et al.*, 1991)**

3.3 UV Disinfection Equipment

3.3.1 Lamps

Ultraviolet light is produced in disinfection systems by electrically powered mercury vapour lamps. The lamps are characterized by both their operating pressure and their output level. The three major types of lamps that are available are:

- Low pressure/low intensity (LP/LI)
- Low pressure/high intensity (LP/HI)
- Medium pressure/high intensity (MP/HI)

These different lamp types are discussed in detail below. A summary is provided in **Table 3-1**. The decision on which lamp to use for a specific plant is dependent upon a number of factors. One major factor is the plant's design flow rate.

3.3.1.1 Low Pressure/Low Intensity Lamps (LP/LI)

These lamps are the conventional UV lamps that have been used extensively since the early 1980s. More than 90% of currently operating UV systems use low pressure/low intensity lamps (Giller, 2000). Low pressure/low intensity lamps operate on the same principle as fluorescent lamps. The lamps consist of a transparent tube with an electrode at each end and UV light is emitted as the result of an electron flow through the ionized mercury vapour between the electrodes. The difference between UV lamps and fluorescent lamps is that fluorescent lamps are coated with phosphorus so that they convert the UV radiation to visible light (USEPA, 1999a). In addition, the UV lamps are enclosed in quartz sleeves to protect them from damage and to insulate them.

Low pressure/low intensity lamps emit UV radiation that is essentially monochromatic at a wavelength of 253.7 nm, which is within the optimal germicidal range for UV light. The spectral power distribution for low pressure/low intensity lamps is shown in the top half of **Figure 3.4**. A small percentage of UV light is also produced at a wavelength of 185 nm. Because UV light at 185 nm

Table 3-1 Comparison of the Different Lamp Types

Parameter	Low Pressure/ Low Intensity Lamps	Low Pressure/ High Intensity Lamps	Medium Pressure/ High Intensity Lamps
Operating Pressure (torr)	10^{-3} to 10^{-2} (vacuum)	10^{-3} to 10^{-2} (vacuum)	10^{2} to 10^{4} (near atmospheric)
Operating Temperature (°C) at Lamp Surface	40 to 50	90 to 250	600 to 800
State of Mercury	Partially vapourized	Partially vapourized	Fully vapourized
UV Spectrum	Monochromatic	Monochromatic	Polychromatic
Input Power (W)	75	190 to 1620	1250 to 5000
Germicidal Efficiency (%)	35 to 40	20 to 40	7 to 15
UV Output in the Germicidal Range (W)	26.7 (64 inch)	40 to 500	87.5 to 750
Effective Lamp Life (hours)	8,000 to 13,000	5,000 to 12,000	5,000 to 8,000
Power Modulation	Not usually	Usually	Yes
Cleaning Method	Manual	Automatic	Automatic
Typical WWTP Size	Small to Medium	Small to Very Large	Medium to Very Large

promotes the formation of ozone, the bulbs of the lamps are made of a glass that absorbs UV light at 185 nm but easily transmits light at 253.7 nm. Ozone formation must be minimized because it is corrosive to the exposed plastic or rubber of the UV equipment.

The filling of low pressure/low intensity lamps is a mixture of mercury and an inert gas such as Argon. The pressure is quite low (10^{-3} to 10^{-2} mm Hg or torr; i.e. vacuum) as is the operating temperature, which is approximately 40 to 50°C (Jeyanayagam *et al.*, 2000). Most of the mercury remains in liquid form during the operation of the lamp with only a small fraction being vapourized. In disinfection systems two standard lamp lengths are commonly used (WEF, 1996): 0.9 m (36 inch) and 1.6 m (64 inch).

The UV output of low pressure/low intensity lamps is quite low. As a result, UV systems using these lamps require a large number of lamps. The input power for one of the 1.6 m lamps is approximately 75 W (Giller, 2000) not including the ballast contribution. Including the ballast contribution, the power consumption is approximately 80 to 85 W per lamp. The output of the 1.6 m lamps at the germicidal wavelength of 253.7 nm is 26.7 W. This translates to a germicidal efficiency in the range of 35 to 40%.

Effective lamp life ranges between 8000 and 13,000 hours (Jeyanayagam *et al.*, 2000). The UV output of the lamps decreases with age. In the design model developed by Darby *et al.* (1995) they assume that the lamp output will decrease to 70% of its initial burned- in value during its operating life.

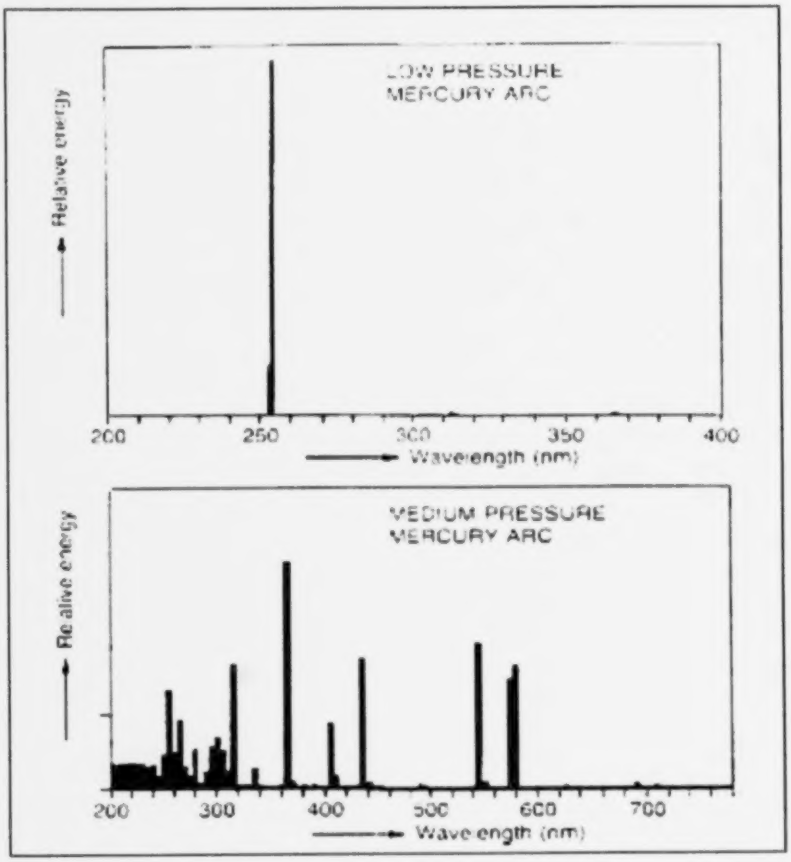


Figure 3.4 **Spectral Power Distributions for Low Pressure and Medium Pressure UV Lamps (Meulemans, 1987)**

Noesen *et al.* (1999) found that used lamp output was only 54% after 8000 hours of operation when compared to new LP/LI lamps after 100 hours of burn-in.

One source indicates that the performance of these LP/LI lamps is optimal at a wastewater temperature of 15.6°C (60°F). Deviations from this temperature in either direction will result in a reduced output of UV light. However, other sources indicate that this effect is minimal with the use of proper quartz sleeves.

In most systems using the traditional low pressure/low intensity lamps, the lamps are either on or off. Their power is not modulated although the newer electronic ballasts allow for this possibility (WEF, 1996).

3.3.1.2 Low Pressure/High Intensity Lamps (LP/HI)

These lamps operate within the same pressure range as conventional low pressure lamps (10^{-3} to 10^{-2} torr; i.e. vacuum) and also produce essentially monochromatic radiation at a wavelength of 253.7 nm.

The operating temperature for these lamps is 90 to 250°C (O'Shaughnessy *et al.*, 2000). The major difference between the low and high intensity lamps is that the low pressure/high intensity lamps have a much higher power output per centimeter of arc length than the low pressure/low intensity lamps and thus require fewer lamps to achieve the same level of disinfection.

Power ratings for low pressure/high intensity lamps range from 190 to 1620 W with a germicidal efficiency ranging from 20 to 30% (O'Shaughnessy *et al.*, 2000). This translates to a germicidal UV output per lamp ranging from approximately 40 to 500 W (considering the entire range of possible lamp power ratings). Low pressure/high intensity lamps are generally less efficient than low pressure/low intensity lamps, but are more efficient than medium pressure/high intensity lamps. Some manufacturers claim that LP/HI systems can have germicidal efficiencies of up to 40% depending on the selected ballast. Most low pressure/high intensity systems allow the lamp power to be modulated and have automatic cleaning systems.

The higher power levels used in these lamps, compared to the traditional lamps, are possible due to changes in the size and shape of the lamps, and in the composition of the gas and mercury mixture in the lamps (Suntec *environmental*, 2001). Some manufacturers use an amalgam of bismuth, indium, and mercury in their lamps that helps maintain the ideal mercury vapour pressure over a wide range of lamp operating temperatures.

Effective lamp life for low pressure/high intensity lamps ranges from 5000 to 12000 hours (Scroggs *et al.*, 2000).

3.3.1.3 Medium Pressure/High Intensity Lamps (MP/HI)

A major difference between medium pressure and low pressure lamps is that MP/HI lamps operate at pressures of 10^2 to 10^4 mm Hg (or torr) and temperatures of 600 to 800°C (WEF, 1996). In the medium pressure/high intensity lamps the mercury is completely vapourized and the pressure is set by the amount of mercury added during the manufacturing process. As with the low pressure lamps, an inert gas such as argon is also present in the lamp.

The lamp again consists of a transparent glass tube with electrodes on each end. A thin molybdenum foil connects the electrodes to the external connections (WEF, 1996). In addition, the lamp ends are coated with a reflective heat-resistant material that helps maintain lamp temperature and keeps the pinches cooler.

The lamps range from 20 to 50 cm in length with a diameter of approximately 2.5 cm (O'Shaughnessy *et al.*, 2000). Quartz sleeves are provided around the lamps for protection and insulation. Automatic cleaning mechanisms are provided for these lamps to minimize fouling which can be of more importance with these lamps due to the increased scaling potential at the higher operating temperature. The cleaning mechanisms can be mechanical wipers or mechanical wipers augmented with chemical cleaning. Systems with chemical cleaning use an acid solution contained in a chamber incorporated into the mechanical wiper.

Medium pressure lamps have much higher input and output power levels than low pressure/low intensity lamps so that fewer lamps are required to achieve the same level of disinfection. Unlike low pressure lamps, the operating temperature of these lamps is not affected by the wastewater temperature (WEF, 1996).

The input power varies with UV manufacturer. The currently available lamps range from 1250 W to 5000 W (O'Shaughnessy *et al.*, 2000). Unlike low pressure/low intensity lamps, power modulation is a common feature of systems with medium pressure lamps.

The disadvantage of the medium pressure lamps is that they are less efficient than the low pressure lamps. They convert about the same percentage of their input power to radiation but this radiation is polychromatic with wavelengths ranging from 180 to 1370 nm (USEPA, 1999a). Only a small portion of this radiation is in the optimal germicidal range as shown in the bottom half of **Figure 3.4**. Germicidal efficiencies for medium pressure lamps range from 7 to 15% (O'Shaughnessy *et al.*, 2000). This translates to a germicidal UV output per lamp ranging from 87.5 to 750 W (considering the entire range of possible lamp power ratings).

Effective lamp life for medium pressure lamps ranges from 5000 to 8000 hours. As with the low pressure lamps, the lamp output decreases with age.

MP/HI UV lamp systems are most commonly used for medium-to-high wastewater flow rate applications (e.g., typically greater than 25 MLD) or at sites with space constraints because fewer lamps are required and the system footprint is smaller than for low pressure UV lamp systems (Metcalf & Eddy, 2003).

3.3.2 Ballasts

Ballasts are transformers that regulate the current to the lamps and stabilize the light output. They also provide sufficient voltage to start the lamp. Without a ballast, the current in a mercury vapour lamp keeps increasing until the lamp overheats and destroys itself (Suntec *environmental*, 2001).

In older UV systems, electromagnetic ballasts were used. Electromagnetic ballasts consist of a core of stacked steel laminations surrounded by a copper or aluminum coil. The traditional low pressure/low intensity lamps are instant start lamps (Suntec *environmental*, 2001). In systems using these lamps, each electromagnetic ballast powers two lamps. A step-up transformer is used to create the starting arc without pre-heating the electrodes (Suntec *environmental*, 2001).

Electromagnetic ballasts are reliable but have many disadvantages. The major disadvantage is that they are inefficient and lose much of their input energy as heat. As a result, they require cooling systems and temperature monitors. Other problems with these ballasts are their noise, size, weight, and inability to modulate the power supply to the lamps (WEF, 1996).

Most modern UV systems use electronic ballasts. These ballasts are smaller, lighter, and more energy efficient than electromagnetic ballasts. They also allow for power modulation so that the lamps can be dimmed or brightened (WEF, 1996). In this case rapid start lamps with continuously heated electrodes are used (Suntec *environmental*, 2001). Electronic ballasts can supply one or more lamps each.

Although electronic ballasts produce much less heat than electromagnetic ballasts, they still produce enough heat to cause problems unless adequate cooling is provided (Suntec *environmental*, 2001). Most UV systems, particularly medium pressure systems, are equipped with ballast cooling systems such as fans or heat exchangers with a circulating coolant such as propylene glycol. Some manufacturers use submerged ballasts in their systems that are cooled by the wastewater. Besides being self-cooled, submerged ballasts offer the advantage of reducing the size of the cabinets needed to house the UV electrical equipment. The disadvantage can be water ingress and difficultly for access and maintenance.

3.3.3 Reactors

Ultraviolet disinfection reactors are available in both open channel and closed chamber configurations. Most systems that use low pressure lamps (both low and high intensity) have open channel reactors while systems with medium pressure lamps have enclosed reaction chambers. The medium pressure system manufactured by Trojan Technologies Inc. is installed in an open channel, but its lamps are contained in an enclosed reaction chamber. Aquionics manufactures medium pressure systems contained in closed pipes.

3.3.3.1 Open Channel Reactors

In open channel reactors, the lamps can be arranged horizontally and parallel to the wastewater flow or vertically. A horizontal system is shown in **Figure 3.5**, while a vertical system is shown in **Figure 3.6**. In both cases the lamps are completely submerged in the flowing wastewater.

Horizontal and Parallel to Flow Systems

Horizontal lamp, open channel configurations are the most common UV disinfection installations in the municipal wastewater sector (WEF, 1996). The lamps used are low pressure and can be either low or high intensity. Horizontal systems consist of modules of lamps that are hung together side-by-side in banks in an open channel. The modules span the width of the channel to form a bank. Each module consists of a metal support frame that contains a number of evenly spaced lamps enclosed in quartz sleeves. The modules typically contain 8 or 16 lamps. An example of a module used in a horizontal system is shown in **Figure 3.7**.

Horizontal systems normally have multiple channels and multiple banks per channel as shown in **Figure 3.5**. This provides redundancy so that cleaning and maintenance tasks can be performed without interrupting the operation of the UV system. It also allows for the effective use of automatic flow and dose pacing where lamps are turned on or off or dimmed based on the flow rate (WEF, 1996).

In a horizontal bank of lamp modules, the lamps are spaced uniformly. Lamp spacing is an important design parameter for UV disinfection systems. The lamps must be closely spaced to optimize reactor performance. If the lamps are spaced too far apart, the reactor efficiency is reduced due to short-circuiting of flow. The optimum lamp spacing is a project-specific decision and takes the following

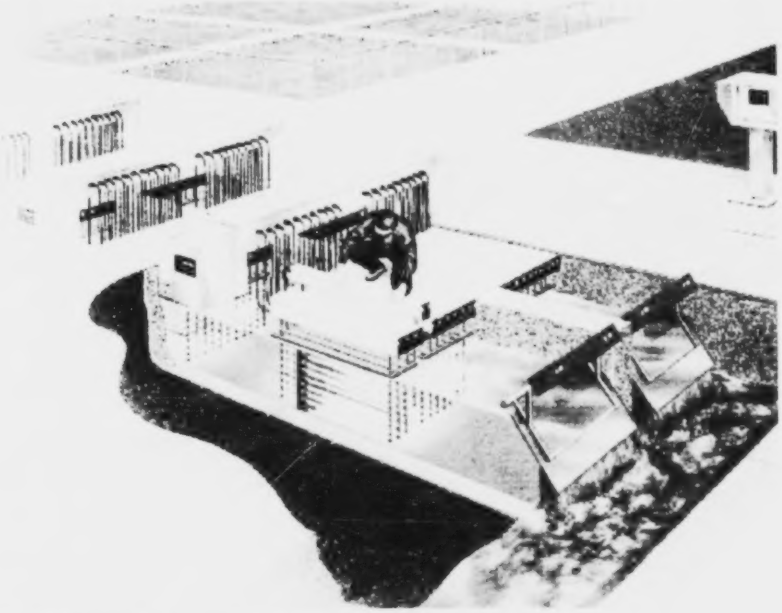


Figure 3.5 Open Channel Reactor with Horizontal Lamps (Trojan Technologies Inc., 2000)

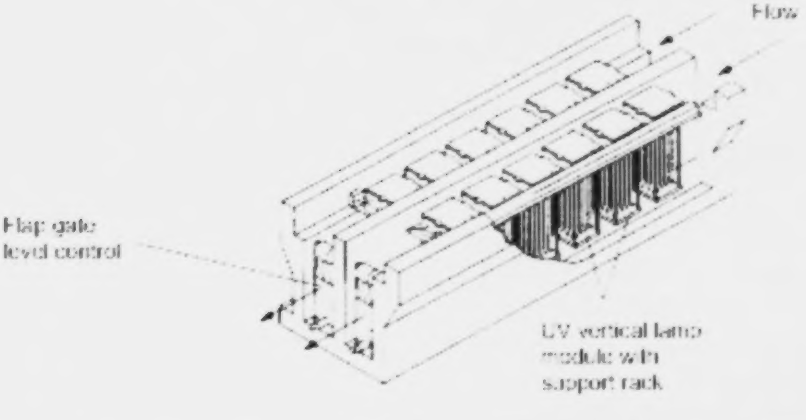


Figure 3.6 Open Channel Reactor with Vertical Lamps (USEPA, 1999b)

parameters into consideration: minimum/design UV transmittance of the wastewater, UV-C output of lamps at the end of their lifetime, quartz sleeve diameter and UV dose requirement. Chiu and Buffle (2001) found that the reduction in reactor efficiency caused by increased lamp spacing could not be compensated for by increasing the lamp output in horizontal systems. The standard lamp spacing used in horizontal open channel systems employing LP/LI lamps is 75 mm (3 inches) (WEF, 1996).

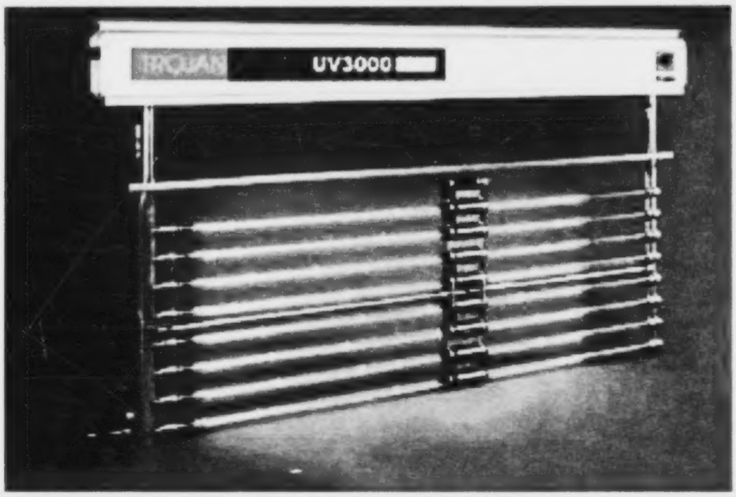


Figure 3.7 **UV Lamp Module for a Horizontal System (Trojan Technologies Inc., 2000)**

In low pressure/low intensity horizontal systems, the lamps are cleaned manually. This involves removing individual modules by hand or an entire bank of lamp modules with a crane and cleaning them in a cleaning station. The cleaning station can range in complexity from a drained area equipped with a hose and cleaning solution to an ultrasonic dip tank (WEF, 1996).

In low pressure/high intensity systems, each module is usually supplied with a cleaning mechanism that wipes over the quartz sleeves at regular intervals. The wiping mechanism may be purely mechanical or may also contain a chamber filled with an acid cleaning solution (e.g. Lime-Away) that is not considered toxic at the concentrations that would enter the wastewater. If ingested, it is very toxic since it is a strong acid.

Vertical Systems

Vertical lamp systems for open channel installations were introduced as alternatives to horizontal systems in the late 1980s. As in horizontal systems, the lamps are low pressure and can be either low or high intensity. Vertical lamp modules consist of an open rectangular frame that rests on the bottom of the channel in an upright position. The lamps are oriented so that they are perpendicular to the floor of the channel. A vertical module typically contains 40 lamps that are arranged in a staggered 8 by 5 array (WEF, 1996) as shown in **Figure 4.4**. Vertical lamp modules are more like banks in horizontal systems because they contain a large number of lamps. In vertical systems, failed lamps are easier to replace than in horizontal systems because individual lamps can be removed with the module in place.

Manufacturers of vertical systems claim that the vertical bulb arrangement creates more radial turbulence than in horizontal systems and minimizes the impact of failed lamps. When a bulb fails in a horizontal system, portions of the flowing wastewater may not come in contact with a lamp. In vertical systems this is less likely because of the staggered orientation of the lamps.

Lamp modules in vertical systems can be arranged side-by-side and/or front-to-back in the channel to form banks (WEF, 1996). An overhead crane is required for removing an entire module from the channel but individual lamps can be removed by hand as mentioned above.

Because of the vertical orientation of the lamps, the channels must be deeper in vertical systems than in horizontal systems. Shorter 1 m (36 inch) lamps are often used in vertical systems to minimize the channel depth as much as possible (WEF, 1996).

Vertical UV lamp systems offer automatic cleaning systems. In the case of low pressure/low intensity units the cleaning system consists of an air scrubber at the bottom of the module. If chemical cleaning is desired, the entire module must be removed from the channel to a cleaning station using a mechanical lifting system. In low pressure/high intensity vertical systems a mechanical wiping system is provided and the air scrub feature is optional.

Another vertical system with low pressure/high intensity lamps has been introduced recently in which each lamp has its own unique partially enclosed reaction chamber. These reaction chambers are placed side by side in an open channel to form a reactor bank. Reactor banks are normally arranged in series. Each reactor has its own automatic cleaning system that combines mechanical and chemical cleaning. For more details see **Section 4.2.4.2**.

3.3.3.2 Closed Channel Reactors

Closed channel reactors are used in systems with medium pressure lamps and certain LP/HI lamp systems. There are two basic designs:

- Horizontal and parallel to flow lamps enclosed in a reaction chamber that is housed in an open channel
- Horizontal and perpendicular to flow lamps mounted in a closed chamber that is connected to flanged pipes

Horizontal and Parallel to Flow Systems

A diagram of this type of system is shown in **Figure 3.8**. The lamps are enclosed in a reaction chamber that is completely enclosed except for the inlet and outlet. The reaction chamber is positioned at the bottom of an open channel below a concrete insert (labeled as E in **Figure 3.8**). In this system each module is a staggered array of eight lamps. Each module has its own dedicated mechanical removal system that allows for replacement of failed lamps. Removing a module in this system requires that the system be taken out of service (WEF, 1996).

The modules are arranged side-by-side to form a bank that spans the width of the reaction chamber. There are two banks per reaction chamber; there is one bank near the inlet of the chamber and one bank near the outlet of the chamber. Reaction chambers can be arranged in both series and parallel to increase capacity and provide redundancy.

In horizontal and parallel to flow medium pressure systems, an automatic mechanical/chemical cleaning system is provided. This system consists of a sealed 51 mm (2 inch) wiper mechanism that

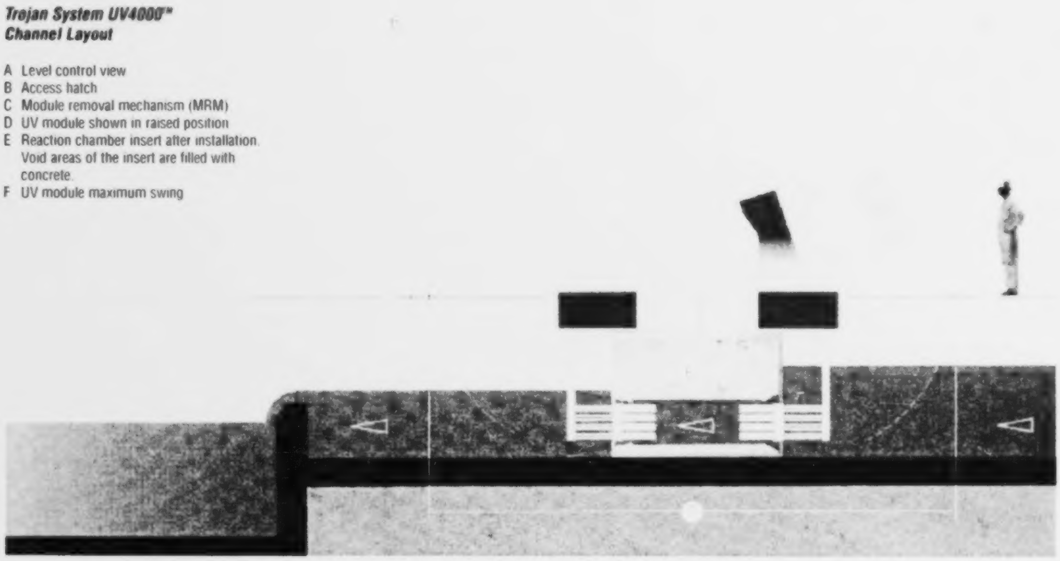

Trojan System UV4000™
Channel Layout
A Level control view
B Access hatch
C Module removal mechanism (MRM)
D UV module shown in raised position
E Reaction chamber insert after installation. Void areas of the insert are filled with concrete.
F UV module maximum swing

Figure 3.8 **Medium Pressure, Horizontal and Parallel to Flow System (Trojan Technologies Inc., 2000)**

contains an acid cleaning solution. The cleaning solution is circulated under pressure within the wiper as it moves along the lamps (WEF, 1996). The modules are cleaned sequentially within each bank. The solution is changed when it becomes less effective. A small amount may be left on the lamps, but the amounts are minor and not toxic.

Horizontal and Perpendicular to Flow Systems

Photographs of this type of system are shown in **Figure 3.9** and **Figure 3.10**. Horizontal and perpendicular to flow systems are termed inline systems. The closed reaction chamber is connected to flanged pipes at its inlet and outlet and contains one or more circular medium pressure lamp banks that are perpendicular to the wastewater flow. The number of lamps per bank varies with the model. Multiple reaction chambers can be arranged in series and parallel to increase capacity and provide redundancy. The flow in these systems can be pumped or gravity fed.

In these systems, failed lamps can be removed while the system is operating (WEF, 1996). The lamps can be accessed through watertight ports on the side of the reaction chamber. As with open channel vertical systems, the lamp orientation in closed channel, horizontal and perpendicular to flow systems minimizes the impact of failed lamps.

An automatic mechanical cleaning system is provided with the horizontal and perpendicular systems. An optional mechanical/chemical wiper is also available that is similar to the one used in horizontal and parallel to flow systems with medium pressure lamps.

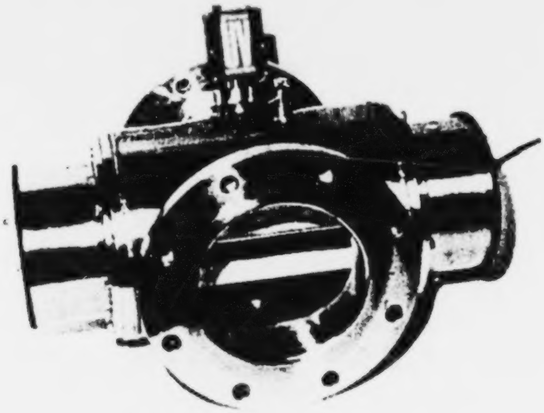


Figure 3.9 Medium Pressure, Horizontal and Perpendicular to Flow Reaction Chamber (Aquionics Inc., 2001)

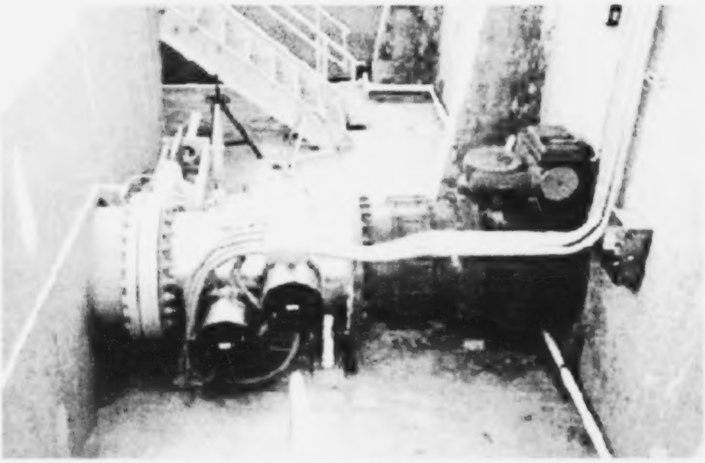


Figure 3.10 Installed Medium Pressure, Horizontal and Perpendicular to Flow System (Goodman and Mills, 2001)

3.3.4 Hydraulic Considerations

The key issue with regard to hydraulics in UV reactors is the establishment of plug-flow conditions (with radial mixing) while minimizing headloss (WEF, 1996). This is controlled by the reactor geometry, the lamp array geometry, and the flow rate of wastewater to the UV disinfection system.

Lamp orientation and spacing plays a significant role in controlling the degree of radial mixing found in a UV reactor. Unfortunately, the designer has little control over this factor because the lamp arrays are provided by the UV equipment manufacturer.

The important factors for the designer to consider with respect to establishing plug-flow conditions in open channel systems are the width and length of the channels and the design of the structures at the reactor inlet and outlet (WEF, 1996). The channels are normally designed to be relatively long and narrow.

Inlet and outlet structures are often required with an open channel system. Inlet structures are often stilling plates or submerged dams, which are used to establish a uniform flow pattern across the channel (WEF, 1996). Outlet structures are weirs or flap gates, which are used for level control as discussed in **Section 3.3.5**. It is suggested in WEF (1996) that the inlet and outlet structures be a minimum of 2 m (5 ft) from the closest lamp array to allow a uniform flow pattern to be established in the UV reactor. More recent California Title 22 guidelines for water recycling (California Code of Regulations, 2003) do not include this minimum separation distance requirement but rather specify that the flow coming into the UV system must be uniform across the array. The consultant together with the UV system manufacturer should ensure that the flow is uniform in cross section.

In open channel UV systems, headloss is seen as a drop in the liquid surface level throughout the system and is a function of the inlet velocity and the reactor geometry. The headloss encountered in UV systems is usually not important in terms of power consumption but is an important operational issue with regards to the UV reactor (WEF, 1996). Two important issues to consider are the liquid level at the reactor inlet and the liquid level at the reactor outlet. These levels should not coincide with the top of irradiated zone in the UV reactor (WEF, 1996). Otherwise, short-circuiting or the incomplete immersion of lamps can occur. Another important consideration is that the headloss should not be minimized to the point where it leads to inadequate radial mixing in the reactor. Radial mixing is turbulent mixing across the width or diameter of the reactor.

According to WEF (1996), open channel systems with inlet velocities ranging from 5 to 50 cm/s and headlosses of no more than 10 cm achieve an acceptable balance between creating plug-flow conditions and minimizing headloss.

3.3.5 Level Control

In open channel UV reactors the liquid level must be maintained to within set limits. In horizontal systems for example, the level is usually kept to within 12 to 18 mm of the target level. If the level is too high, the fluid near the surface will receive a low dose of UV light. If the level is too low, entire lamps (in the case of horizontal systems) or portions of lamps (in the case of vertical systems) may be exposed.

Level control is usually accomplished using counterbalanced flap gates, fixed weirs or motorized downward opening penstocks. When flap gates are used for vertical systems, a base wall is usually required (WEF, 1996).

In closed channel systems with lamps that are horizontal and parallel to flow, level control is necessary to ensure that the level does not drop below the top of the reaction chamber. Fixed weirs are normally used in these systems as shown in **Figure 3.8**. In closed channel systems with lamps that are horizontal and perpendicular to flow, level control is not necessary because the reaction chamber is completely flooded.

3.3.6 Instrumentation and Control

UV systems can be equipped with remote system control centers that house the control and monitoring equipment for the system. The controllers may be programmable logic controllers (PLCs) or microprocessor based. These systems are usually capable of monitoring the following items:

- Status of individual lamps (e.g. on, off, or failed)
- Status of individual ballasts
- System power
- System time
- Flow rate provided by plant effluent flow meter
- UV intensity within the reactor (normally there is one intensity sensor per bank of lamps)
- Water level in reactor (low water level sensors are usually standard)
- Temperature (important when using medium pressure lamps because they will overheat if the wastewater is not flowing; alternatively, the lamps can be shut off if the flow rate is low)

Alarms are provided to alert operators to events such as failed lamps and low UV intensity. Alarm histories and summaries may be provided by the control system as well. Optional items that can be monitored in some systems include the following:

- % transmittance of the wastewater
- Turbidity of the wastewater
- Duration of the operation of each individual lamp and the number of times it has been turned on or off

Periodic re-calibration of the sensors is required. It is especially important to ensure that the intensity sensor is re-calibrated on a regular basis (e.g. once per year). In addition, the intensity sensor should not be placed too high or too low in the chamber and should be kept free of fouling through routine maintenance and regular automatic cleaning.

The control system can range from manual to fully automatic. The main functions of automatic control systems are to maintain an adequate UV dose while conserving energy and lamp life, to shut off modules when lamps are exposed to air or if the temperature in the chamber becomes too high, and to control any automatic cleaning mechanisms.

The dose delivered by a UV system is controlled by dimming or brightening lamps, shutting lamps or entire banks on or off, and taking channels out of service (if possible). The control of the dosage may be based on flow rate measurements (flow pacing) or on both flow rate and UV intensity measurements (dose pacing). When using dose pacing some systems also make use of wastewater transmittance and turbidity measurements.

The frequency of automatic cleaning is usually set by the operator and implemented by the automatic control system. Cleaning systems can usually be manually controlled as well.

3.3.7 Additional Design and Operational Considerations

System reliability is an important consideration when designing a UV disinfection system. System redundancy and backup power should be considered to ensure adequate disinfection performance in the event of lamp or bank failures, channel cleaning, lamp cleaning, and power outages. This is especially important in water reuse applications.

As mentioned in **Sections 3.3.3.1** and **3.3.3.2**, redundancy can be provided by using multiple banks or reaction chambers per channel (in series) and/or multiple channels (in parallel). This allows disinfection to continue during lamp or bank failures and when banks are taken out of service for lamp or channel cleaning operations. Having multiple banks and/or channels also provides flexibility in handling varying wastewater flow rates.

Specific guidelines for extra banks and channels are provided in some regions of North America. For example, the Recommended Standards for Wastewater Facilities (Great Lakes – Upper Mississippi River Board, 1997), commonly referred to as the 10 State Standards, require that at least two banks in series be provided in each channel. In order to meet the California Title 22 guidelines (California Code of Regulations, 2003), Tchobanoglous *et al.* (1993) recommend that redundancy be provided in the form of one standby bank per channel or one or more standby channels. When treating water for reuse, the Georgia Department of Natural Resources (2002) recommends the use of redundant banks or reactors and requires that UV systems have the ability to isolate and bypass all UV reactors in a system.

System redundancy can be enhanced by ensuring that spare lamps, modules, ballasts, and quartz sleeves are stored on-site by operations personnel (Tone *et al.*, 2000). The storage of spare lamps is mandated in some cases (Georgia Department of Natural Resources, 2002).

Power supply reliability is another important component of the overall UV disinfection system reliability. Because power supply reliability is site-specific, it is beneficial to study historical power monitoring data in order to determine the frequency and duration of power interruptions to be expected at a site. This helps guide the designer in making provisions for backup power. In cases where continuous disinfection is required, regulations may dictate that disinfection be provided during all power outages (Great Lakes – Upper Mississippi River Board, 1997).

In order to ensure that a UV system remains in service during power failures, dual source/dual feed power systems or automatically activated standby power generators are often used. Low pressure/low intensity lamps for example require roughly 100 watts of standby power for each lamp (USEPA, 1999).

An important consideration with regards to standby power is the cycle time required by the UV lamps. Automatic standby power generators normally require time to start and the power interruption can still be enough to cause the lamps to lose arc. When this happens the lamps require a cycle time to re-start which can include cool-down and warm-up periods as long as 10 to 15 minutes, depending on the lamps. LP/LI lamps have short cycle times similar to fluorescent lamps but high intensity lamps, especially MP lamps, can have significant cycle times. The actual cycle times are lamp and system specific. In order to overcome this problem, one solution is to also have a battery-powered uninterruptible power supply (UPS) that can handle short interruptions and can also provide power until the standby generators are activated.

An alternative to standby power is to provide a backup chlorination/dechlorination system (North Carolina Division of Water Quality, 2001). In addition to standby power, another reliability feature recommended by Tchobanoglous *et al.* (1993) is to divide the UV banks between different power distribution boards.

The size of a UV disinfection system should be considered when assessing its redundancy and backup power requirements. In very small systems (e.g. < 0.2 MLD) it may be adequate to keep spare lamps and modules on-site and have a standby power supply (North Carolina Division of Water Quality, 2001). Larger facilities should consider redundant banks and/or channels, spare parts, and provisions for power outages. In addition, facilities should consider developing a contingency plan to follow during power failures (Swift *et al.*, 2002).

Proper cleaning and maintenance is essential for effective disinfection performance. Automatic and/or manual cleaning of the quartz sleeves is important to ensure that the performance of the lamps is not compromised. A regular lamp replacement schedule is also important because lamps age due to solarization of the lamp wall (Giller, 2000) and deterioration of the electrodes (USEPA, 1999). The aging of the lamps results in a decreased lamp output over time.

Ballasts are usually replaced every 10 years while quartz sleeves are usually replaced every 5 years (USEPA, 1999b). One manufacturer claims that quartz sleeves for MP/HI systems last for 5 years while those for LP/LI and LP/HI lamp systems usually last for 20 years.

Chapter 5 provides additional information on design criteria and considerations for UV disinfection systems.

3.4 Summary of UV Disinfection Equipment

A summary of the UV disinfection equipment discussed in **Section 3.3** along with some additional information is given in **Table 3-2**. The table presents the equipment configurations available for each type of mercury vapour lamp along with the manufacturers of each configuration. For each configuration, the manufacturers shown are those that actively market that particular configuration. As shown, more options are available, in terms of manufacturers, for low pressure/high intensity lamps. One manufacturer, Trojan Technologies Inc., supplies configurations for all three types of lamps.

3.5 Costs

3.5.1 General Costing Information

The costs associated with ultraviolet disinfection systems include capital costs as well as annual operating and maintenance costs. Capital costs include costs for the following items (USEPA, 1999b):

- UV equipment
- Installation
- Structural modifications
- Electrical
- Miscellaneous

Annual operating and maintenance costs include costs for (Darby *et al.*, 1995)

- Electrical power
- Lamp replacement
- Ballast replacement
- Quartz sleeve replacement
- Cleaning chemicals and supplies
- Staffing requirements
- Equipment repair

3.5.2 Site Specific Costs

Site-specific capital and O&M costs found in the literature and some costs encountered in recent Hydromantis consulting work are presented in **Table 3-3**. All systems considered treat secondary effluent except for one that treats blended primary and secondary effluent. The design transmittance ranges from 45 to 65%. The plant sizes range from 4 MLD to 662 MLD (peak wet weather flow). The following types of systems are considered:

- Low pressure/low intensity (vertical systems and horizontal systems)
- Low pressure/high intensity (horizontal systems and vertical one lamp per reactor systems)
- Medium pressure/high intensity (horizontal-parallel-to-flow systems and horizontal-perpendicular-to-flow systems)

Table 3-2 Summary of UV Disinfection Equipment for Treating Secondary Wastewater Effluent

Lamp Type	Lamp Orientation	Reactor Type	Main Manufacturers	Cleaning System	Control System for Maintaining UV Dose
LP/LI	horizontal & parallel	open channel	Trojan Technologies	manual cleaning	flow pacing
	vertical	open channel	ONDEO Degremont	manual cleaning + optional air scrubber	flow staging (rows of lamps on/off)
LP/HI	horizontal & parallel	open channel	Suntec *environmental*	Automatic mechanical wiper	flow/dose pacing
			Trojan Technologies	Automatic mechanical/ chemical wiper	flow/dose pacing
			WEDECO–Ideal Horizons	Automatic mechanical wiper	flow/dose pacing
	vertical	open channel	ONDEO Degremont	Automatic mechanical wiper + optional air scrubber	flow staging (rows of lamps on/off)
			UV Systems Technology* (Ultra Guard)	Automatic mechanical/chemical wiper	flow/dose pacing
MP/HI	horizontal & parallel	closed chamber in open channel	Trojan Technologies	Automatic mechanical/chemical wiper	flow/dose pacing
	horizontal & perpendicular	closed chamber connected to flanged pipes	Aquionics	Automatic mechanical wiper (optional mechanical/chemical wiper available)	flow pacing

* UV Systems Technology has recently given the rights to manufacture the Ultra Guard UV product line to BCA the Clearwater Group, British Columbia. USFilter markets and supplies the product line in North America.

Nomenclature:

LP/LI = low pressure/low intensity lamps
LP/HI = low pressure/high intensity lamps
MP/HI = medium pressure/high intensity lamps

The published information cited in **Table 3-3** can be consulted for additional system details including the dates of system installation. The costs given in **Table 3-3** are those reported in the references. To account for inflation, construction cost indices such as the Engineering News-Record (ENR) cost index can be used to update the reported costs. For example, we can update the capital cost from the

Table 3-3 Site Specific Costs from the Literature and Other Sources

Information Source	Type of Treatment	ADWF (MLD)	PWWF (MLD)	UVT (%)	SS (mg/L)	Discharge Limit (MPN/ 100mL)	Type of system	# of channels	# of banks per channel	# of lamps	Dose (mW s/cm^2)	Capital Costs ($ Cdn.)	Annual O & M Costs ($ Cdn.)*
Hydromantis (2001)	Activated Sludge	1.5	4.05	65	15	200	LP/HI (horizontal & parallel)	1	1	18	20 (design minimum	184,000 (total installed cost)	N/A
Veenstra (2001)	Activated Sludge	N/A	56.8	N/A	N/A	California Title 22 Guidelines for Water Reuse	MP/HI (horizontal & parallel)	1	4	N/A	N/A	4,769,231 (equipment and electrical only)	N/A
Scroggs *et al.* (2000)	Biofilter-Activated Sludge	37.4	72.5	45	20	23 (30 day median)	LP/HI (horizontal & parallel)	2	4	896	100	3,692,308 (total construction and installation cost)	261,538 (labour, power, & replacement lamps)
Christeson and Fath-Azam (2000)	Activated sludge (+ some primary effluent)	N/A	662	45	30 to 45	200 (30 day median)	MP/HI (horizontal & parallel)	4	2	720	N.D.	13,390,769	469,231
Jeyanayagam *et al.* (2000)	Activated Sludge	20.4	41.6 (peak hour)	60	30	200	LP/LI (vertical)	2	1	560	55	363,846 (equipment and channel modifications)	25,252 (not including staffing)
							LP/LI (horizontal & parallel)	2	2	576	55	584,615 (equipment and channel modifications)	45,677 (not including staffing)
							MP/HI (horizontal & parallel)	1	2	40	44	487,692 (equipment and channel modifications)	31,787 (not including staffing)
							MP/HI (horizontal & perpendicular)	1	2	24	44	414,060 (equipment and channel modifications)	25,217 (not including staffing)

Table 3-3 Site Specific Costs from the Literature and Other Sources (contd.)

Information Source	Type of Treatment	ADWF (MLD)	PWWF (MLD)	UVT (%)	SS (mg/L)	Discharge Limit (MPN/ 100mL)	Type of system	# of channels	# of banks per channel	# of lamps	Dose (mW s/cm²)	Capital Costs ($ Cdn.)	Annual O & M Costs ($ Cdn.)ᵃ
Perspective of UV System Manufacturer	Activated Sludge	N/A	121	65	< 10	200	LP/HI (vertical, one bulb per reactor)	N/A	N/A	60	N/A	1,150,000 (equipment bid cost)	N/A
							MP/HI (horizontal & parallel)	N/A	N/A	N/A	N/A	1,000,000 (equipment bid cost)	N/A

ᵃ A conversion factor of $1 Cdn./$0.65 US was used to convert figures reported in $US to $Cdn

Nomenclature:
LP/LI = low pressure/low intensity lamps; LP/HI = low pressure/high intensity lamps; MP/HI = medium pressure/high intensity lamps
ADWF = average dry weather flow; PWWF = peak wet weather flow; UVT = Ultraviolet Transmittance; SS = suspended solids; O&M = operating and maintenance
N/A = not available

Hydromantis (2001) project to September 2003 dollars by multiplying the capital cost ($184,000) by the ENR construction cost index for September 2003 (6741) divided by the average annual ENR construction cost index for 2001 (6342). The updated capital cost in this case is $196,000.

Generic pricing for a range of plant sizes from small to large and with poor (i.e., UV transmittance of 50%) or good (i.e., UV transmittance of 70%) secondary effluent was obtained from the major manufacturers for comparison. These equipment capital and O&M cost estimates for alternative lamp and process types are described in **Chapter 7**.

4 Manufacturers Review

4.1 Introduction

Many manufacturers and suppliers provide UV systems for industrial and municipal water and wastewater disinfection applications. However, only a few are well known in the industry for municipal wastewater disinfection and these will be reviewed in this section. The section begins with a long-list of manufacturers determined from a variety of sources and then narrows in on the major players in wastewater applications. This approach was used to ensure all available systems were considered.

A number of manufacturers of full-scale UV irradiation systems for wastewater disinfection have been identified. This section provides a brief overview of the major manufacturers of UV technologies for wastewater disinfection applications, and includes information on:

- Respective technologies
- Process characteristics, configurations and components
- Unique/distinguishing features
- Examples of full-scale facilities in Canada and results of site visits

4.2 Equipment Manufacturers

This section reviews the manufacturers and suppliers providing UV disinfection systems in North America. The first section provides a long-list of potential manufacturers and suppliers that are then short-listed to those actually providing UV for municipal wastewater applications.

4.2.1 Overall List

A long list of potential UV suppliers was obtained by researching the Water Environment Federation's manufacturers/suppliers list. **Table 4-1** provides this list and a brief review of each.

4.2.2 Primary Manufacturers

A number of the manufacturers and suppliers in **Table 4-1** only provide UV systems for non-wastewater applications or provide other types of disinfection systems (e.g. ozone). Two of the manufacturers only provide UV systems for water applications in North America, these being:

- Capital Controls, affiliated with Severn-Trent (and Hanovia)
- Calgon Carbon

Based on the review of the long list of manufacturers and suppliers, the following six manufacturers are reviewed in detail as major providers for the municipal wastewater market:

- Aquionics (Inline and Closed Chamber series systems; MP/HI lamp, horizontal and perpendicular to flow) in association with Berson, BV
- ONDEO Degremont (Aquaray 40 for open channel systems; LP/LI and LP/HI lamps, respectively, all vertical and perpendicular to flow)

Table 4-1 Long List of Potential UV Manufacturers and Suppliers

UV Manufacturers Long List (Based on WEF search)		
Company	**Address/Phone/ Web**	**Discussion**
Aquionics Inc.	P.O. Box 18395, Erlanger, KY 41018 USA (606) 341-0710 Fax (606) 341-0350 *www.aquionics.com*	Manufacturer/supplier, in-vessel system, indicates experience for various sizes (10-100 MGD)
Ashbrook Corporation	11600 East Hardy, Houston, TX USA *www.ashbrookcorp.com*	Manufacturer, noted on website little info
Atlantic Ultraviolet Corp.	375 Marcus Blvd. Hauppauge, NY 11788 USA (631) 273-0500 Fax (631) 273-0771 *www.atlanticuv.com*	Manufacturer, low pressure low intensity system
Calgon Carbon Corp.	P.O. Box 717, Pittsburgh, PA 15230-0717 USA (800) 422-7266 Fax (412) 787-6324 *www.calgoncarbon.com*	Manufacturer; clean water only. Medium pressure high intensity system no longer marketed for wastewater applications.
California Environmental Controls	P.O. Box 489, Whittier, CA 90608-0469 USA (562) 693-5257 Fax (562) 693-5257	Distributor
Capital Controls Co. (Severn Trent)	3000 Advance Lane, Colmar, PA 18915 USA (215) 997-4000 Fax (215) 997-4062 *www.capitalcontrols.com*	Manufacturer, Small systems <3 MGD only? Horizontal and vertical
Ecometrics	130 W. Main St., Silverdale, PA 18962 USA (215) 453-9800 Fax (215) 453-1000 *www.ecometrics.com*	Supplier, no info on web on UV product; now part of Capital Controls
Hayward Industrial Products	900 Fairmount Ave., Elizabeth, NJ 07207 USA (908) 351-5400 Fax (908) 351-7893 *www.haywardindustrial.com*	Manufacturer, plastic pipe, strainers, filters, no UV
Hydro-Aerobics, Inc.	PO Box 16327, Houston, TX 77222-6327 USA (281) 449-0322 Fax (281) 987-2134	Distributor? Can't find info on net
Hydromatix Inc.	10450 Pioneer Blvd., Bldg 3 Santa Fe Springs, CA 90670 USA (562) 903-7786 Fax (562) 944-9264 *www.hydromatix.com*	Manufacturer – Ion exchange, zero discharge
Jacuzzi Bros.	12401 Interstate 30, P.O. Box 8903, Little Rock, AR 72219-8903 USA (501) 455-1234 *www.jacuzzibros.com*	Manufacturer – Whirlpools, expected limited w/w experience

Table 4-1 Long List of Potential UV Manufacturers and Suppliers (contd.)

UV Manufacturers Long List (Based on WEF search)		
Company	**Address/Phone/ Web**	**Discussion**
ONDEO Degremont Inc.	P.O. Box 71390, Richmond, VA 23255-1390 USA (804) 756-7600 Fax (804) 756-7643 *www.ondeodegremont.com*	ATSI (Aqua Technical Sales Inc.) local supplier, low pressure systems (low and high intensity), generally vertical
Orec Ozonation Systems/Osmonics	5951 Clearwater Drive, Minnetonka, MN 55343 USA (602) 931-7332 Fax (602) 931-7727 *www.osmonics.com*	Ozone and other equipment, no UV and no w/w
Osmonics Inc.	5951 Clearwater Drive, Minnetonka, MN 55343 USA (612) 933-2277 Fax (612) 933-0141 *www.osmonics.com*	Same as above
Ozonia North America	491 Edward H. Ross, Drive Elmwood Park, NJ 07407 USA (201) 794-3100 Fax (201) 794-3358	Ozone generation
Piper Environmental Group, Inc.	20118 Forest Avenue, Cupertino, CA 95014 USA *www.peg-inc.com*	Service Provider, Nothing on web
ProMinent Fluid Controls Inc.	RIDC Park West 136 Industry Drive, Pittsburgh, PA 15275-1014 USA (412) 787-2484 Fax (412) 787-0704	Manufacturer, Mainly metering pumps
Spectronics Corp.	956 Brush Hollow Road, P.O. Box 483, Westbury, NY 11590 USA (800) 274-8888 Fax (800) 491-6868 *www.spectroline.com*	Manufacturer, Specialty applications and sterilization
Suntec *environmental*	106 Rayette Road Unit 1, Concord, L4K 2G3, Canada *www.suntecuv.com*	Manufacturer
Tipton Environmental	4476 State Route 132, Batavia, OH 45103 USA (513) 735-2777 Fax (513) 735-1485 *www.wastewaterdepot.com*	Manufacturer, no equipment or experience noted
Trojan Technologies Inc.	3020 Gore Road, London, ON N5V 4T7, Canada (519) 457-3400 Fax (519) 457-3030 *www.trojanuv.com*	Manufacturer, low pressure, low intensity and medium pressure high intensity units

Table 4-1 Long List of Potential UV Manufacturers and Suppliers (contd.)

UV Manufacturers Long List (Based on WEF search)		
Company	**Address/Phone/ Web**	**Discussion**
UltraTech Inc.	Unknown	Creemore WPCP
UV Systems Technology Inc. (Ultra Guard)	2800 Ingleton Ave., Burnaby, C.-B. V5C 6G7, Canada (604) 451-1069 Fax (604) 451-1072 *www.ultraguard.com*	Manufacturer
Water-Right, Inc.	1900 Prospect Court, Appleton, WI 54915 USA (920) 739-9401 Fax (920) 739-9406	Small Systems, water applications
WEDECO-Ideal Horizons	3520 Westinghouse Blvd., Charlotte, NC 28273 USA (704) 716-7600 Fax (704) 716-7601 email: munsales@wedecouv.com *www.wedecouv.com*	Manufacturer, UV equipment

- Suntec *environmental* (LPX open channel systems (where LPX stands for low pressure, extra output); LP/HI lamps, horizontal and parallel to flow)
- Trojan Technologies (Systems UV3000, UV3000*Plus* and UV4000 for open channel systems; LP/LI, LP/HI, MP/HI lamps, respectively, all horizontal and parallel to flow)
- UV Systems Technology/Ultra Guard (Ultra Guard Single Lamp Reactor that can be placed in open channels; LP/HI lamps, vertical and perpendicular to flow)
  - UV Systems Technology has recently given the rights to manufacture the Ultra Guard UV product line to BCA the Clearwater Group, British Columbia. USFilter markets and supplies the product line in North America.
- WEDECO–Ideal Horizons (TAK 55 Type open channel systems; LP/HI lamps, horizontal and parallel to flow)

Contacts have been made with representatives from each of these companies and information has been obtained for most, which is summarized in this section of the report. A general information request form was distributed to all of the systems manufacturers for completion. Copies of completed sheets returned by the manufacturer or partially completed by Hydromantis are included in **Appendix A**. In some cases, lamp replacement costs and pilot plant rental costs have been reported. More detailed information on capital and operating and maintenance (O&M) costs together with specified system sizes and designs for defined generic wastewater characteristics (i.e., representing secondary treated effluent produced by a suspended growth aerobic process, at low, medium and large flow rates) are reported in **Chapter 7**.

4.2.3 Details for Each Primary Manufacturer

The primary suppliers each provide one or more of the lamp types discussed previously (i.e., either low pressure/low intensity, low pressure/high intensity, or medium pressure/ high intensity.) The other main difference is the orientation of the lamp, either horizontal or vertical. The manufacturers are summarized separately in the following section below. **Figure 4.1** provides an overview of the lamp technologies provided by each manufacturer/supplier for biologically treated wastewater applications. The information in **Figure 4.1** reflects the information provided by the manufacturers/suppliers in the information request forms. Some manufacturers produce systems that are not actively marketed and are therefore not shown in **Figure 4.1**.

4.2.4 Overview and Comparison of the Different Manufacturers

Each of the six main manufacturers is discussed below.

4.2.4.1 ONDEO Degremont

ONDEO Degremont has offered UV disinfection systems since 1992. Corporate experience in the wastewater field is based on 105 years in the industry. Two systems are available for the disinfection of wastewater:

- Low pressure, conventional or low intensity system
- Low pressure, high intensity system

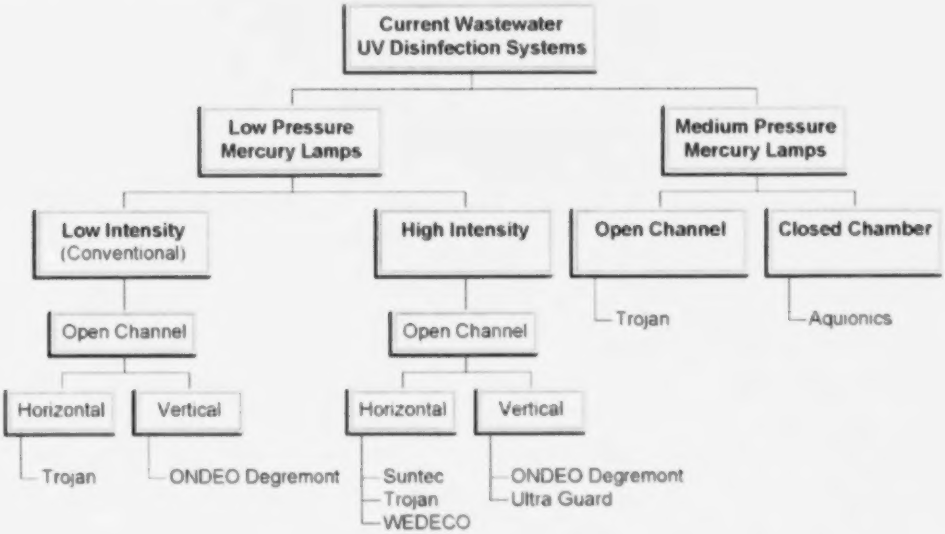

Current Wastewater UV Disinfection Systems
Low Pressure Mercury Lamps
Medium Pressure Mercury Lamps
Low Intensity (Conventional)
High Intensity
Open Channel
Closed Chamber
Trojan
Aquionics
Open Channel
Open Channel
Horizontal
Vertical
Horizontal
Vertical
Trojan
ONDEO Degremont
Suntec
Trojan
WEDECO
ONDEO Degremont
Ultra Guard

Figure 4.1 **Summary of Manufacturers' Equipment by Type of Lamp for Secondary Treated Effluent Disinfection**

The low pressure, low intensity system has been available for the last 11 years, and the low pressure, high intensity system was made available in the last 2 years. Both systems are referred to as Aquaray systems. Aquaray® 40 VLS is the low intensity system, and Aquaray® 40 HO VLS is the high intensity system. Abbreviations stand for high output (HO) and vertical lamp system (VLS). A typical layout used for both systems is shown in **Figure 4.2**.

Common features of the Aquaray system are:

- Open channel systems
- Vertical orientation with staggered lamp array
- 40 lamp modules (8 wide, by 4 long)
- Lamp on/off pacing instead of individual bulb modulation
- Air sparge cleaning, as well as wiper cleaning on high intensity lamps

ONDEO Degremont has over 300 UV installations worldwide. Their largest facility in Canada is at the Barrie WWTP at 57 MLD (15 US MGD) and includes 1200 lamps, utilizing low pressure, low intensity lamps installed in 1998. ONDEO Degremont has high intensity system at two plants in Ohio that are the closest to Southern Ontario.

The decision on whether to recommend low or high intensity lamps is based on a number of factors, including plant size. Generally, facilities larger than 19 MLD (5 US MGD) are considered for high intensity. For smaller facilities the general "rule-of-thumb" is 1 module of lamps (i.e. 40 lamps) per million gallons (4500 m^3/d). The manufacturer claims its UV system is applicable to a wide range of flows from 2 to greater than 450 MLD (0.5 to greater than 120 US MGD)

Power conservation is obtained by turning rows of lamps off as flow allows. In "off" mode lamps are still powered but at a reduced rate to maintain lamp life. Lamp life varies with a life expectancy of 13,000 hours, but is guaranteed for 8,600 hours. Each ballast operates two lamps. Ballasts are cooled by fans, one for low intensity lamps, two for the high intensity lamps with added features. Additional features for high intensity lamps include fins on ballasts and deflector plates in the channel.

Power consumption varies as well but is generally 75 watts for the low intensity and 165 watts for the high intensity lamps.

Staggered lamps and flow baffles (with high intensity units) create turbulent conditions and reduce or eliminate wall effects. Also vertical orientation ensures that with a lamp off, wastewater still encounters repeated areas of maximum intensity UV energy, that may not be the case for horizontal orientated lamps as shown in **Figure 4.3**.

Both vertical systems can incorporate an optional air scrub feature that prevents excess deposition of solids in the disinfection channel and retards the rate of fouling. The high intensity system also can be provided with a fully automatic in-channel wiper cleaning system that reduces routine cleaning.

Figure 4.2 Typical Aquaray 40 Vertical Installation

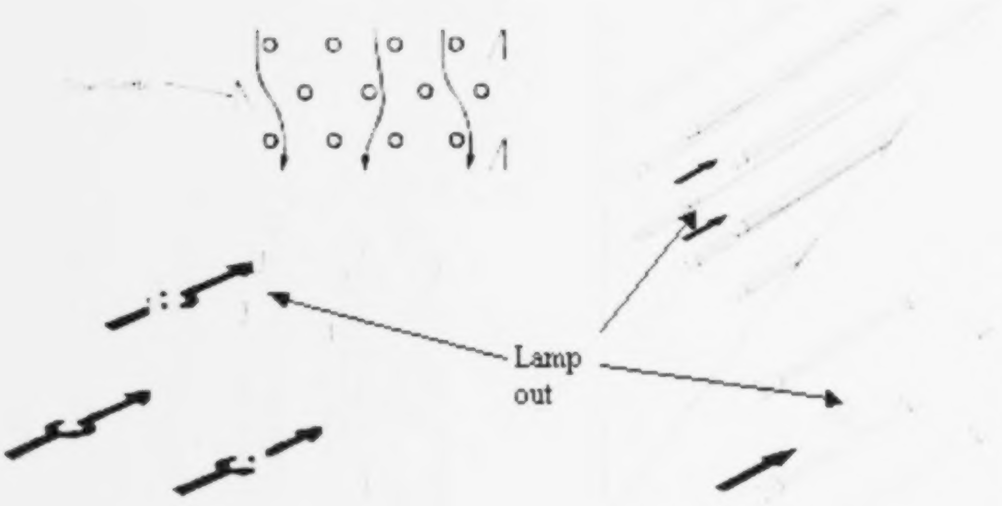


Figure 4.3 Vertical Versus Horizontal Lamp Systems

The wiper utilizes a single plate that wipes all lamps in a bank (i.e. 40 lamps at one time). The layout of a high intensity bank is shown in **Figure 4.4**, including the lamps, wiper system and ballast with cooling fans.

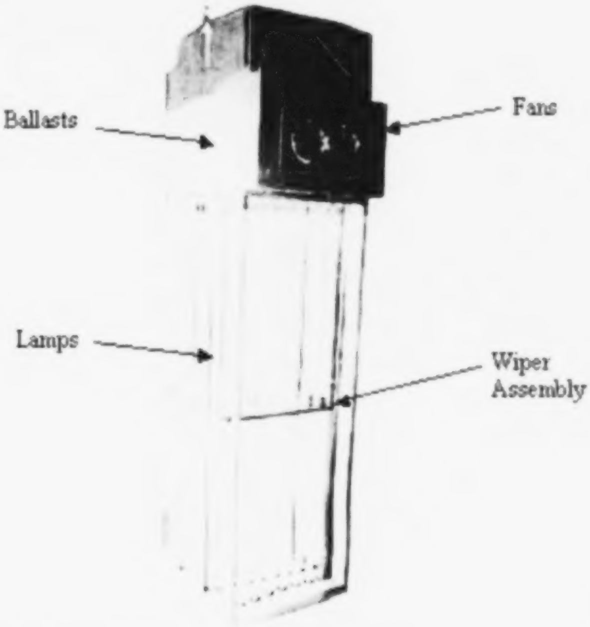


Figure 4.4 Vertical High Intensity Lamp Module

Level control is generally accomplished by using either flap gates or straight edge weirs.

4.2.4.2 UV Systems Technology Inc./Ultra Guard

UV Systems Technology Inc. (UVST) has been involved with UV technology since 1995 (development) with the first installation of their unit in 1998. Their UV system is referred to as Ultra Guard. UV Systems Technology is wholly owned by Services Systems International Ltd. (SVSY). UV Systems Technology has recently given the rights to manufacture the Ultra Guard UV product line to BCA the Clearwater Group, British Columbia. USFilter markets and supplies the product line in North America.

The Ultra Guard system is a low pressure, high intensity UV system with the highest rated low pressure lamps used for UV disinfection in terms of energy output. Its lamps are rated at 1620 W with a germicidal output of 504 W per lamp. The standard arrangement of the Ultra Guard system is presented in **Figure 4.5**. The figure outlines a 10-lamp system with 2 banks (2 pass).

The system is made up of a number of main components including:

- Diffuser Plate – First element in system, spans channel, breaks up flow and prevents large suspended particles from hitting UV quartz sleeve. Openings are 45 mm
- Mounting Plate – Spans channel and supports UV reactors. Also directs flow through each reactor and supports inlet gate for each reactor

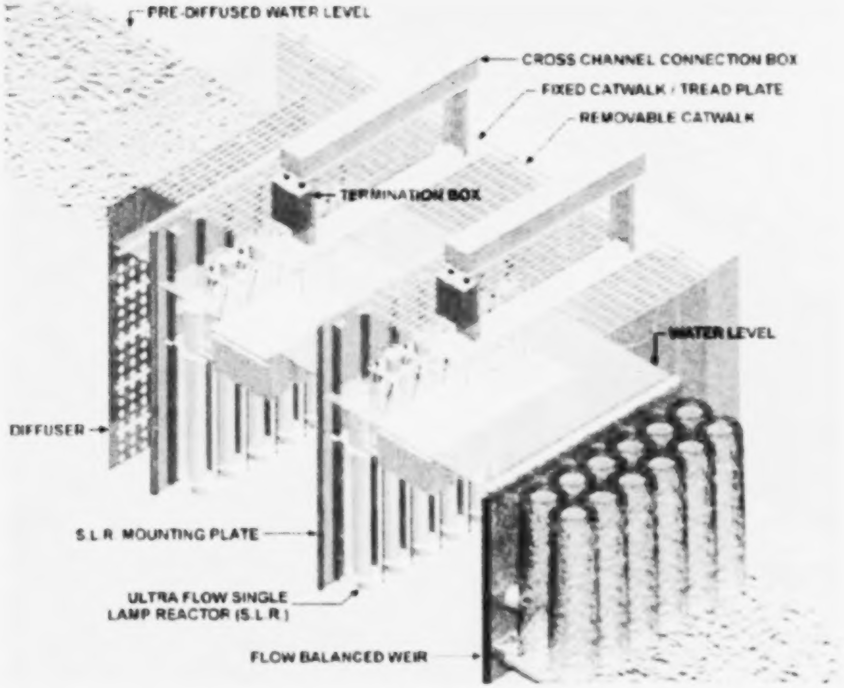

PRE-DIFFUSED WATER LEVEL
CROSS CHANNEL CONNECTION BOX
FIXED CATWALK / TREAD PLATE
REMOVABLE CATWALK
TERMINATION BOX
WATER LEVEL
DIFFUSER
S.L.R. MOUNTING PLATE
ULTRA FLOW SINGLE LAMP REACTOR (S.L.R.)
FLOW BALANCED WEIR

Figure 4.5 Ultra Guard Typical Installation

- Inlet Gates – Each reactor has an upstream gate to isolate each unit; these can be motorized as a recommended upgrade
- Single Lamp Reactor (SLR) – Reactor is an autonomous, self-contained, fully submersible unit containing the reaction chamber, lamp enclosure, power supply enclosure, and automatic cleaning system
- Flow Balancing Weir – Used to maintain submergence of lamps

Contained in the SLR are the reactor chamber, UV lamp and lamp power controller. **Figure 4.6** shows the SLR in detail. The reactor is connected to the gates, such that influent is directed to one or more reactors. The UV system influent is directed around the quartz sleeve through the annular space between the quartz sleeve and the cylindrical reactor wall. Hydraulic mixing is enhanced by vertical rods that are located on the reactor wall as shown in **Figure 4.7**. These vertical rods deflect the effluent towards the quartz sleeve ensuring maximum exposure of the microorganisms to the UV light.

The mercury vapour low pressure/high intensity lamps are characterized by a germicidal efficiency (i.e. wavelength of 253.7 nm) of 25 to 35% subject to the applicable set point. Operating temperature of the lamps ranges from 60°C to 140°C. Air circulation between the lamp and the quartz sleeve is also reported to maintain a constant temperature along the lamp surface and is induced by a recirculation

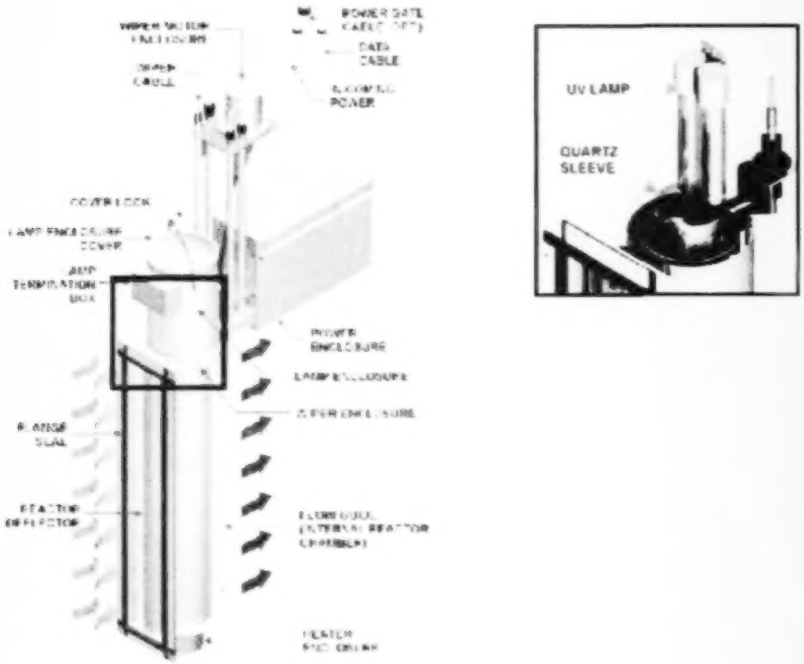

WIPER MOTOR ENCLOSURE
POWER DATA CABLE (OPT)
DATA CABLE
WIPER CABLE
INCOMING POWER
COVER LOCK
LAMP ENCLOSURE COVER
LAMP TERMINATION BOX
POWER ENCLOSURE
LAMP ENCLOSURE
WIPER ENCLOSURE
FLANGE SEAL
REACTOR DEFLECTOR
FLOW GUIDE (INTERNAL REACTOR CHAMBER)
HEATER ENCLOSURE
UV LAMP
QUARTZ SLEEVE

Figure 4.6 Single Lamp Reactor

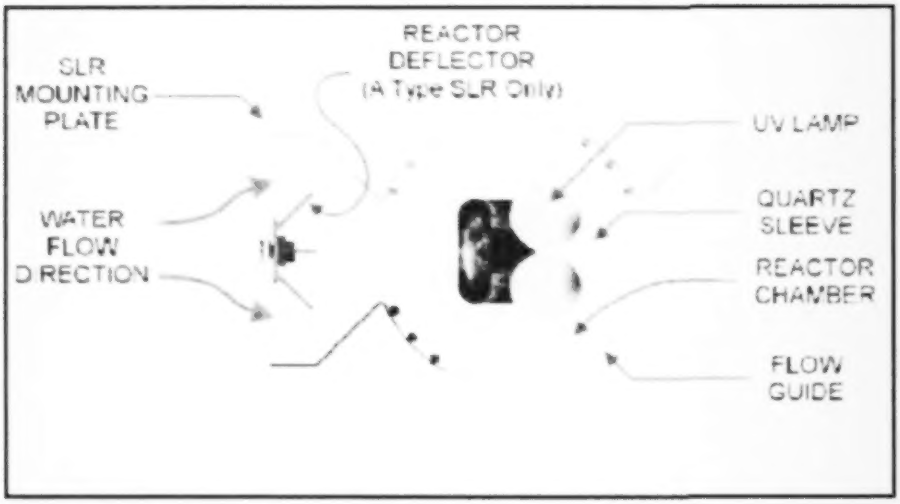

SLR MOUNTING PLATE
REACTOR DEFLECTOR (A Type SLR Only)
UV LAMP
WATER FLOW DIRECTION
QUARTZ SLEEVE
REACTOR CHAMBER
FLOW GUIDE

Figure 4.7 Reactor Details

fan in the sealed unit. The lamps have a physical length of 1352 mm, but a developed tube length of 4,200 mm since the lamp is folded back on itself as shown in **Figure 4.8**.

The Ultra Guard lamp technology and manufacturing capability were acquired from the worldwide established electrical conglomerate, Asea Brown Boveri (ABB) of Switzerland.

The automatic cleaning system includes a double-ring wiper that encircles the quartz sleeve. The cleaning solution, a biodegradable detergent, is injected into an absorbent material located between the two rings. The cycling sequence is controlled by the microprocessor controller.

An electric, floor-mounted lifting system capable of lifting the entire SLR module is provided with the base package. The lifting device is used for maintenance such as algae removal and channel cleaning needs. It is not required to fully remove the SLR to change the lamps or conduct most other maintenance operations. However, the lift is required to partially lift the reactor to conduct this work.

Some of the unique features of the Ultra Guard UV system are:
- Highest rated low pressure, high intensity UV lamp
- Vertical, individual reactor design
- Ability to isolate each reactor and module lamps – large turndown capability
- Unique modular design to facilitate scale-up with an increased degree of flexibility

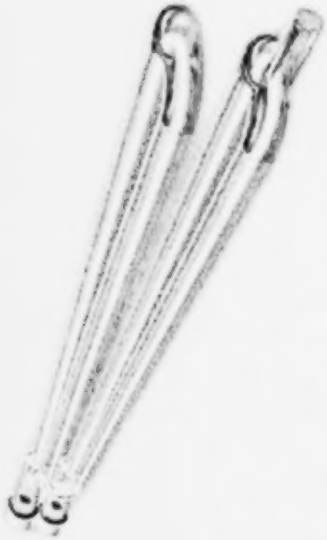


Figure 4.8 Ultra Guard UV Lamp

Although a newer company and system with fewer operating sites, there are a number of sites in North America. References from US Filter/Wallace & Tiernan indicated 10 sites of which seven have been delivered. Of the seven, three were delivered in November or December 2001 and may not have been commissioned at the time of this report. Excluding the Toronto combined sewer overflow (CSO) site, the referenced sites are generally small plants with peak flow capacities less than 27 MLD, averaging a peak flow of 13 MLD. Similarly excluding Toronto, the maximum number of lamps being used is 18, with an average of 7.6 lamps.

4.2.4.3 SUNTEC environmental

Suntec *environmental* manufactures low pressure, high intensity (LP/HI) UV irradiation systems for municipal wastewater disinfection applications worldwide. They do not currently supply systems for drinking water disinfection. The company is based in Concord, Ontario where it has an R&D and manufacturing facility. Suntec *environmental* is a new company formed in 1998, but employs several senior technical personnel with many years of experience in the field of wastewater UV disinfection R&D, engineering, manufacturing, and sales.

The first commercial applications of the Suntec *environmental* LPX200 system, based on a 200-W UV lamp technology, were two facilities installed in November 2000. One of these was installed at a WWTP in Deseronto, Ontario that included a 32-lamp system to treat a peak design flow of 5.5 MLD (1.5 US MGD). There are currently 29 LPX200 installations in North America and Asia, with another 19 systems scheduled for installation by mid-2003. The largest of these is a 189 MLD (50 US MGD; peak design flow) WWTP application in Huntsville, Alabama operational as of September 2002.

The LPX UV Disinfection series uses a modular concept that permits installations into field-fabricated open concrete channels for flow rates up to and greater than 380 MLD (100 US MGD). Available process controls range from simple manual control to a more sophisticated PLC-based distributed control system.

Suntec *environmental* offers various configurations including package plants and open channel design for a range of flow rates. For small applications of up to 3 MLD (0.85 US MGD), a package plant is available that comprises a stainless steel closed channel, modular lamp racks with 2 to 8 lamps, level control weir, power distribution system and monitoring and control equipment. Pictures of the packaged plant and a module containing eight lamps are shown in **Figure 4.9** and **Figure 4.10**, respectively. The Open Channel LPX200 UV Disinfection series is specified for peak flow rates of 2 to 115 MLD (0.5 to 30 US MGD). A newly developed LPX500 system, based on a LP/HI 500-W UV lamp is available and will allow for greater cost effectiveness for large flow applications (i.e., 20 to greater than 380 MLD). There are plans for full-scale demonstrations of this technology in 2003.

The LPX200 system is supplied with between 2 to 16 lamps per rack (i.e., module). The horizontal lamps are arranged parallel to flow within the open channel. A typical arrangement comprises two banks of modules in series within a channel, with 5 modules per bank. The number of channels, banks,

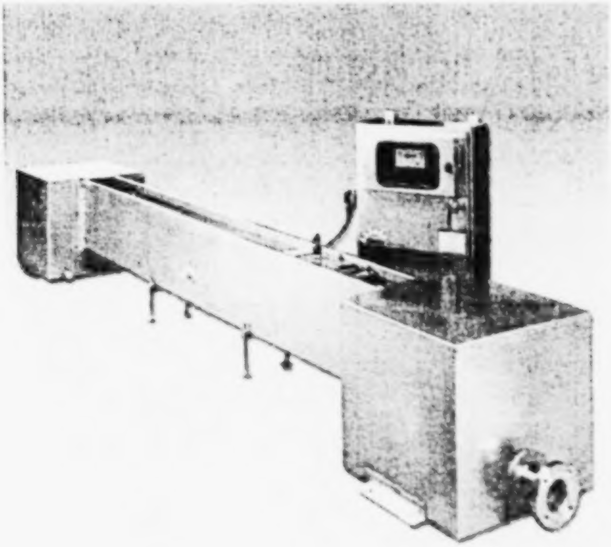


Figure 4.9 LPX200 Package Plant

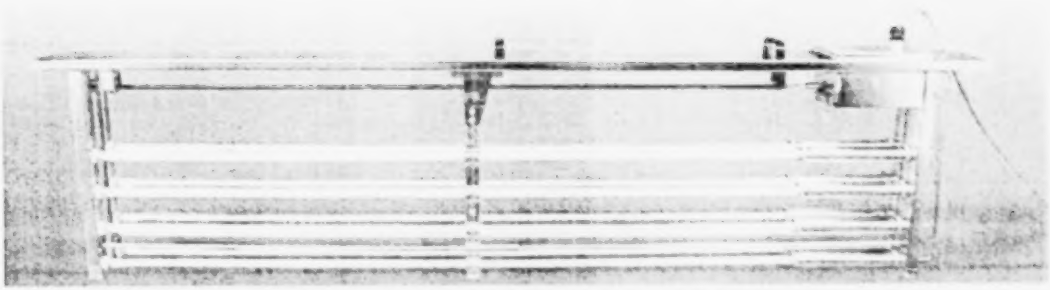


Figure 4.10 LPX200 Module Equipped with Eight 200 W Lamps

modules, and lamps depends on the size of the application and treatment requirements. Plans are for the LPX500 system modules to be supplied with between 2 to 8 of the larger diameter 500 W lamps.

Suntec *environmental's* LPX UV disinfection series offers the following technical features and components:

- Patented ballast technology consisting of an energy efficient submerged electronic ballast design providing cooling by configuration, thus eliminating special mechanical cooling systems
- LP/HI lamps that are 10% longer in length than conventional lamps, are coated for a longer operating life (i.e., >12,000 hours), and have rapid start characteristics

- Automatic non-chemical cleaning system using a patented stainless steel scraper, driven by an electric motor
- A water level control system based on either a stainless steel serpentine weir with drain plug or a counter-weighted stainless steel level control gate
- Control Panels(s) in NEMA 4X rated stainless steel enclosure, housing equipment for power distribution, control and monitoring
- Monitors, alarms and indicators
- Sensor for measuring the average UV intensity within each bank of modules, with user adjustable alarm setpoints

The optional advanced control system includes:

- A PLC-based advanced System Control Center (SCC) for comprehensive on-line process monitoring that will permit flow and dose pacing, including cycling of banks/channels and modulation of lamp output for optimization of energy consumption and lower O&M costs
- Remote control with a PLC host
- Automatic lamp output control between 50 and 100% of maximum power, for dose pacing
- UVT monitor and analyzer

The fully automated LPX series is a low maintenance system. The system is simple to install and start-up as part of a new wastewater treatment facility (i.e., "greenfield" plant installation) or as a retrofit into an existing effluent channel or chlorine contact tank. It includes modular pre-assembled components with quick-connect cables.

Additional specific details on the LPX200 and LPX500 UV disinfection systems are provided in two respective general information sheets in **Appendix A**. This includes costs for replacement lamps and pilot plant rental.

Based on a reference list of full scale LPX200 system installations, 29 systems have been installed to-date, and a total of 49 installations are expected by June 2003. Of these installations, 30 are located in North America, including 7 in Canada. The installations list also shows numerous other municipal wastewater treatment plant applications in Japan supplied by Photoscience Japan, using their low pressure/low intensity (LP/LI) UV lamp technologies.

A preliminary review of the installations list reveals that the Deseronto, Ontario WWTP (5.5 MLD peak design flow) has the longest operational experience and provides year-round wastewater disinfection. A 58 MLD (peak design flow) system was started up in May 2002 at the nearby Georgetown, Ontario WWTP that represents a retrofit of an existing conventional LP/LI system.

4.2.4.4 AQUIONICS

Aquionics Inc., based in Erlanger, KY is a major supplier of medium pressure/high intensity (MP/HI) UV technologies for wastewater disinfection. Aquionics supplies systems to the North American marketplace using technologies developed in conjunction with its two sister companies, Hanovia, UK and Berson, NL. The three companies are members of the worldwide Halma Group, and are global leaders in UV treatment technology for the wastewater industry with more than 70 years of experience and hundreds of installations worldwide. This group of sister companies research, develop, manufacture and market their own lamps. Therefore, in addition to standard process models, the UV disinfection systems can be custom designed for specific applications, if desired. Aquionics also supplies LP/LI and MP/HI UV systems to the North American marketplace for disinfection of drinking water.

Aquionics offers two types of MP/HI UV disinfection systems, namely the "Inline" series and the "Closed Channel" series. Both rely on a closed chamber(s) installed within effluent pipelines. The closed chamber comprises horizontally mounted medium pressure lamps that are configured in a circular arrangement perpendicular to the flow through the pipe. The designs and operational aspects of these systems are outlined briefly in **Section 3.2.3.2** and detailed further below.

The same lamp types (i.e., rated between 2 to 4 kW) can be used in either of the two closed chamber system designs. Various process models are available within these two series, distinguished by the number, type and arrangement of the UV lamps as well as the number of banks in series for the Closed Channel series. Higher power lamps rated at 7.5 kW are now also available for wastewater disinfection applications.

The Inline series is the standard and more cost competitive of the two series and is described in greater detail below. The Inline series units can operate with either gravity flow or pressurized flow (i.e., system pressure tested to 1,034 kPa or 150 psig). Individual units of the Inline series are usually installed in parallel (**Figure 4.11**) to meet standard effluent discharge permits (e.g., less than 200 FU/100 mL geometric mean for fecal coliforms) and for flow pacing and redundancy requirements. For higher degrees of required disinfection (e.g., in water reclamation and reuse applications), the Inline units can be installed in series.

The Closed Channel series units contain two or more banks of lamps in series (**Figure 4.12**) and represent the predecessor of the Inline technology. The closed channel systems are typically used where high peaking factors are involved, where it is desired to have at least two or three banks in series in order to flow-pace. They can only be applied for gravity flow situations.

The Inline 35000 model closed vessel unit, which has the highest rated capacity, is equipped with 24 lamps (4 kW each), while the Inline 25000 model has 16 lamps (4 kW each). Both models have a UV chamber diameter of 0.7 m and pipe length of 1.2 m, with 760 mm (30 inch) flanges for connection to wastewater piping. The UV lamps for these larger models are installed in two separate banks, but not in series. The horizontally mounted lamps in each of the two banks are arranged in a circular pattern, one bank in the top half of the pipe chamber and the second in the bottom half

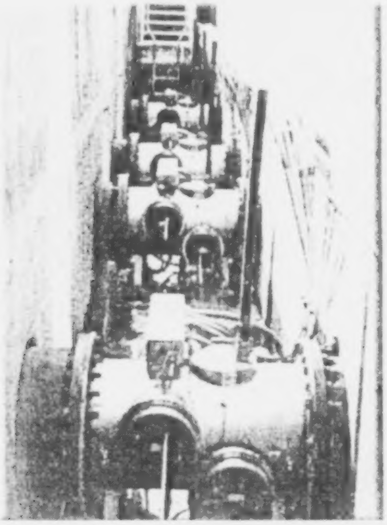


Figure 4.11 **Parallel Installation of Four Model Inline 25000 UV Reactors (Aquionics Inc.)**

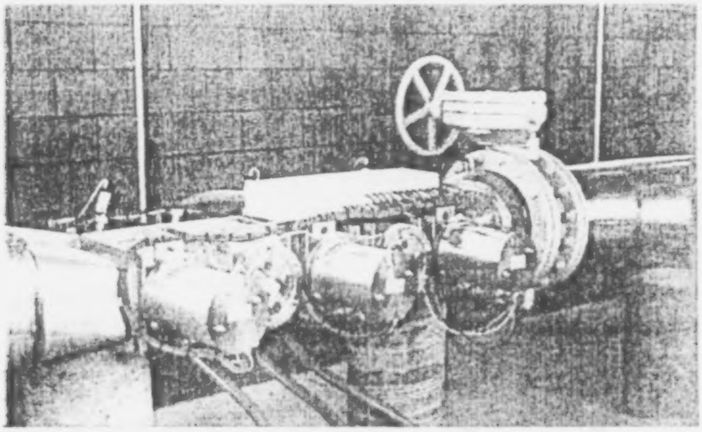


Figure 4.12 **Closed Channel Process with Multiple Banks of Lamps in Series (Aquionics, Inc.)**

(i.e. parallel arrangement) (**Figure 4.11**). Each bank is equipped with one UV intensity sensor, measuring only germicidal UV output from the multi-wave UV lamps and to detect sleeve fouling and changes in wastewater quality.

An automatic cleaning mechanism consisting of an electrical motor driven wiper (with Viton molded wiper rings) is used to clean the UV lamps and UV intensity sensor in each bank. For more demanding applications, the optional patented Ultrawipe cleaning system is available which automatically introduces a small amount of cleaning agent onto the quartz sleeve to assist the mechanical wiper.

The UV chamber is also equipped with a temperature sensor that can trigger an automatic shutdown and alarm in the event of excessive heat buildup in the chamber resulting from lack of flow.

The high germicidal UV energy generated by the Aquionics Inline and Closed Channel series MP/HI UV systems permit compact designs compared with other available disinfection systems. The smaller footprint results in reduced installation costs, and the relatively low number of lamps required, together with the automatic cleaning system, reduces maintenance requirements.

A unique feature of the closed chamber disinfection systems supplied by Aquionics is that they are installed with flanged connections within effluent pipelines. This effective design allows for easy access for quick removal and replacement of lamps whenever necessary. Installations can include retrofits (e.g., easy installations into existing piping or chlorine contact chambers) or new "greenfield" facilities. The system control module and power modules are provided with a NEMA12 degree of protection.

The ballasts used to energize the lamps consist of a coil-wound transformer and heavy-duty capacitors. This represents a reliable option with a 20-year design life, albeit with lower energy efficiency and output control than electronic ballasts. The ballasts are located in fan-cooled cabinets and can control the lamps at three different power levels (i.e., 3.1, 3.5 and 4.0 kW for the Inline 25000 and Inline 35000 systems). The power levels can be manually changed to increase/decrease UV lamp intensity to account for variations in wastewater characteristics and to match disinfection needs, but are primarily provided to increase the lamp power as the lamp ages in order to maintain the same level of UV output from the lamp. Flow-pacing can be achieved by automatically turning parallel units on and off for energy savings.

Additional information on the Inline series UV technology is provided in a completed general information sheet in **Appendix A**. This includes costs for replacement lamps and pilot plant rental.

A reference list of full-scale installations of Aquionics' UV disinfection systems (i.e., various Inline and Closed Channel series models) at municipal WWTPs in North America reveals approximately 100 wastewater disinfection installations. Based on the reference list, the first one was installed in 1988. The three largest facilities range in size from 75 MLD (20 US MGD) peak design capacity (i.e., a facility in New Castle, Indiana consisting of two parallel Inline 35000 model units installed as a retrofit within a chlorine contact chamber) to 150 MLD (40 US MGD) peak capacity for two separate facilities in Yellow River and Crooked Creek, Georgia. The latter two facilities both utilize four Inline 25000 model reactors arranged in parallel. A 450 MLD (120 US MGD peak design capacity) installation is under construction in Cobb County, Georgia and should be operational by June 2002.

Two large Inline disinfections systems located in Gainesville and Yellow River, GA practice year-round disinfection. The Inline 35000 system in New Castle, Indiana operates seasonally. There are currently no wastewater disinfection system installations utilizing Aquionics' technologies in Canada.

4.2.4.5 Trojan Technologies

Trojan Technologies Inc. is a world leader in the number of UV disinfection installations, including more than 2000 in municipal wastewater treatment applications. The company's headquarters are in London, Ontario, with an extensive R&D facility to support a commitment to the ongoing development of innovative technologies. It employs technical personnel involved in computer optimized design, engineering, manufacturing, installation, and R&D. A state-of-the-art technical support center allows technicians to dial up and diagnose problems on-line. The company has a global network of authorized service representatives. H2Flow Equipment Inc. in Concord, Ontario is the local supplier.

Trojan manufactures a full range of UV disinfection technologies (i.e., conventional LP/LI and more advanced LP/HI and MP/HI systems), including a number of different commercial models within each of the three system categories. All three series of UV disinfection systems (i.e., Trojan Systems UV3000, UV3000*Plus*, and UV4000, respectively) are designed to be installed into open channels using horizontal lamp and parallel to gravity flow configurations. Selection, sizing and layout of the most appropriate system and process model for a particular application depends on important site-specific considerations, wastewater characteristics and treatment requirements. Process-specific details are provided below.

System UV3000

The Trojan System UV3000 is utilized for conventional UV disinfection of wastewater in small to medium sized applications. Typical applications are for up to 38 MLD (0-10 US MGD). The LP/LI 87.5-W UV lamps are assembled in modules with either two, four, six, eight or sixteen lamps each. A picture of System UV3000 modules with different numbers of lamps is shown in **Figure 4.13**. Expected lamp life is 10,000 to 15,000 hours, depending upon on/off cycles and the frequency of required cleaning.

The System UV3000 offers the following technical features:

- Entire process and all equipment are designed to operate outdoors
- UV modules can be simply set into place in the open channel
- Energy efficient electronic ballasts are used that can be located within an enclosure in the module frame, with no special mechanical cooling requirements (i.e., air cooled by convection)
- Individual lamp status displayed on each module
- Stainless steel UV detection probe installed in each bank to monitor UV output from the lamps
- Power Distribution Center to distribute power to each UV bank
- Tracking of UV bank elapsed time in operation
- Automatic level controller for maintaining the optimum liquid level in the channel

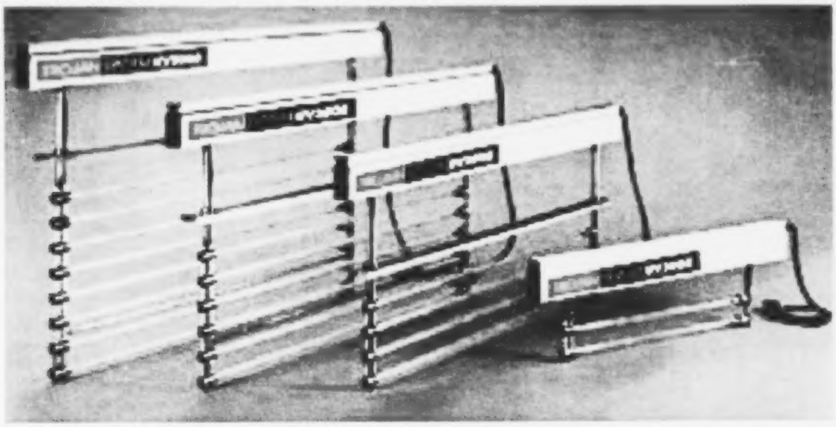


Figure 4.13 System UV3000 Modules with Different Numbers of UV Lamps (Trojan Technologies Inc., 2000)

Advanced system options include:

- Compact, weatherproof System Control Center (SCC) for enhanced process monitoring and control that can be located locally or remotely at the plant's SCADA center
- SCC that permits flow pacing by automatically turning banks of UV lamps on and off in response to flowrate variations, and the cycling of banks/channels, for reduced O&M costs and prolonged lamp life
- On-line UVT monitor

System UV3000*Plus*

The System UV3000*Plus* represents the newest generation wastewater disinfection process offered by Trojan. It utilizes LP/HI 250-W lamp technology and offers advanced process control features and an optional automatic cleaning system. There are more than 100 System UV3000*Plus* installations worldwide, typically involving design capacities of up to 57 MLD (15 US MGD).

The System UV3000*Plus* process is particularly suited for applications involving:

- Lower quality wastewater
- Higher wastewater volumes
- Where sleeve fouling rates are potentially high, and/or
- Where O&M and electricity costs are significant considerations

Owing to the higher UV lamp output, significantly fewer lamps are required than for conventional LP/LI systems, resulting in lower installation costs, reduced space requirements and decreased O&M needs and costs. Furthermore, the System UV3000*Plus* incorporates variable output electronic ballasts that allow UV output to be adjusted (i.e., flow/dose-pacing capability) for effective disinfection, energy conservation, and prolonged lamp life. The ballasts are located within the module frame with no special cooling requirements (i.e., air cooled by convection).

The UV lamps are horizontally mounted in modules installed on a module support rack attached to the open channel wall and arranged parallel to the wastewater flow. Lamp modules contain two, four, six or eight lamps. A photograph of one module with eight lamps and an automatic cleaning mechanism is shown in **Figure 3.7**. Guaranteed lamp life is 8,760 hours of operation, although actual lifetime can be significantly longer. Lamps can be replaced quickly and easily. The System UV3000*Plus* is designed to operate automatically. An advanced PLC or microprocessor-based control center (SCC) is provided for monitoring, control, and alarms. The system features a UV intensity sensor with an optional automated self-cleaning system within each bank of modules.

The System UV3000*Plus* system offers a number of optional technical features, including:

- The SCC can be programmed for flow/dose pacing by automatically and continually adjusting lamp output (i.e., can be ramped between 60-100% of maximum power or switched on or off) based on on-line UV transmittance (UVT) and flow rate measurements. If the optional on-line UVT unit is not used, a single representative UV transmittance value is manually entered into the SCC.
- The SCC can be programmed for cycling of banks/channels, with lead and lag banks automatically switched to equalize lamp operating time.
- Automatic mechanical and chemical self-cleaning process using a patented submersible wiper system with magnetically coupled drive, for cleaning of quartz sleeves while the disinfection system is in operation.
- Cleaning tank to clean individual modules or banks of modules if the automatic cleaning system is not used.

System UV4000

The Trojan System UV4000 uses medium pressure/high intensity UV lamp technology that is capable of effectively disinfecting a wide range of wastewaters (i.e., primary, secondary, and tertiary effluent, combined sewer overflows, stormwater and process water) in medium to very large flow rate applications. The high output of the 2.8 kW lamps results in the requirement of 90% fewer lamps and much more compact systems than for conventional LP/LI systems. Installation costs and labour requirements are significantly reduced. The process can be applied for high volume and difficult wastewater applications that are not feasible for the LP/LI systems. There are more than 250 System UV4000 installations worldwide, typically involving design capacities of greater than 26 MLD (7 US MGD), although a low-flow model UV4000LF can be applied for peak design flow rates of 4 to 38 MLD (1 to 10 US MGD).

The modular units each comprise two banks of modules with horizontally mounted lamps in an end-to-end series arrangement. The units are installed in open channel, gravity flow configurations. Multiple UV banks can be arranged in series in each channel for more demanding applications such as water reclamation projects or for meeting redundancy requirements. The modules typically contain between 4 and 24 2.8 kW lamps each. A group of parallel modules forms a lamp bank. The guaranteed lamp life is 5,000 hours of operation, but can be longer depending upon the number of on/off cycles.

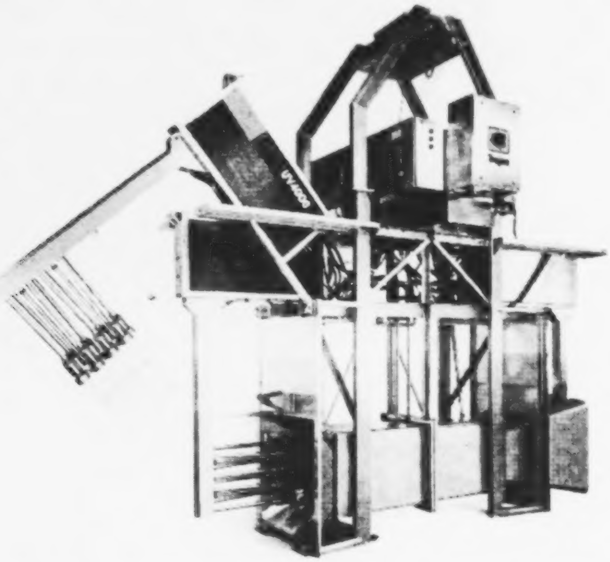


Figure 4.14 Trojan System UV4000 Unit (Trojan Technologies Inc., 2000)

Modulation of the power output enhances lamp life. A schematic of the System UV4000 unit is provided in **Figure 3.8** and a picture is shown in **Figure 4.14**.

The System UV4000 offers a number of standard advanced technical features for enhanced process monitoring and control and ease of maintenance, including:

- Variable output electronic ballasts that allow the UV output of the high intensity lamps to be continually adjusted (i.e., flow/dose-pacing) for effective disinfection, energy conservation and savings, and prolonged lamp life.
- Advanced PLC-based control system for flow/dose pacing, based on continuous on-line effluent monitoring including flowrate and UV transmittance (UVT) measurements, by automatically turning banks of UV lamps on and off and continually adjusting lamp output (i.e., can be ramped between 30 and 100% of maximum power) to maintain effective disinfection while minimizing energy requirements and O&M costs.
- An automatic mechanical and chemical self-cleaning process that can proceed while the disinfection system is in operation and can be controlled by timer or UV intensity measurements from the sensor in each lamp bank.
- Automatic level control device designed for site-specific applications to ensure submergence of the bulbs.
- Module Removal Mechanism utilizing a reversible electric winch to raise individual modules from the channel to facilitate lamp replacement, when required.

The System UV4000 relies on a propylene glycol recirculation system for cooling of the ballast. The ballast life expectancy for all three systems is claimed to be a minimum of ten years. There is a restart delay of a number of minutes for MP/HI lamp systems in contrast to the LP/LI and LP/HI lamps.

Additional information on the Trojan System UV3000, UV3000*Plus* and UV4000 technologies is provided in the respective general information sheets **(Appendix A)**.

A reference list of full-scale Trojan System UV3000*Plus* and System UV4000 installations in North America for UV disinfection of municipal wastewater is available. There are a number of WWTPs utilizing these technologies in Southern Ontario. A number of large installations for design flow rates of greater than 380 MLD (100 US MGD) exist, including the 590 MLD (155 US MGD) System UV4000 facility at the Gold Bar WWTP in Edmonton, Alberta for the disinfection of activated sludge process effluent.

4.2.4.6 WEDECO-Ideal Horizons

WEDECO-Ideal Horizons has more than twenty-five years of experience in the development and application of UV disinfection systems. This involves technology R&D and systems design, installation and commissioning. The company is highly diversified and strongly positioned in all major categories of UV disinfection and is well established internationally with worldwide service capabilities. ENV Treatment Systems Inc. in Etobicoke, Ontario is the local supplier.

WEDECO's wastewater disinfection technologies consist mainly of low pressure/high intensity UV irradiation systems using their variable output Spektrotherm amalgam lamp with which the company has over 15 years of experience. The TAK-55 series UV disinfection systems utilize 300 - 360 W lamps with reported maximum UV-C outputs of 125 - 150 W at 254 nm. The lamps are powered by electronic ballasts that provide variable and stepless output control for dose-pacing. The TAK series systems' electronic ballasts are protected by temperature controlled (i.e., cooled or heated) NEMA12 (indoor) or NEMA 4X (outdoor) enclosures. The guaranteed life of the electronic ballasts is 30,000 hours.

The dose-paced control technology together with the high output lamps result in reduced energy consumption and relatively compact system designs. It is claimed that the process can deliver a given quantity of UV irradiation in the UV-C range using almost four times less energy than an equivalent medium-pressure lamp system for potential operating cost savings. O&M costs are further reduced by the lamps' large surface area and extra high purity quartz glass construction, allowing for a long guaranteed operating life of greater than 12,000 hours.

The TAK series was specifically engineered for disinfection of municipal wastewaters, with various design configurations available depending on wastewater characteristics. The systems are modular in design to facilitate installation into open channels, allowing for practically unlimited flow capacities. The UV lamps are horizontally mounted in modules and arranged in parallel to the gravity-driven wastewater flow. Each bank of UV lamps is equipped with one UV intensity sensor. The systems include a precise level control technology engineered on a project-specific basis, based on a variety of weir or gate options. Flow control baffles are available, if necessary.

Figure 4.15 shows a UV bank consisting of multiple modules containing Spektrotherm lamps, while **Figure 4.16** depicts a TAK disinfection system with UV banks in series in parallel open channels.

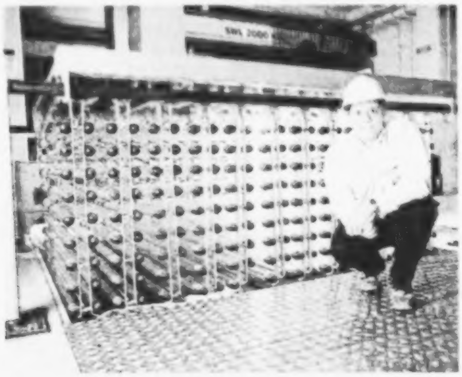


Figure 4.15 UV Bank with Multiple Modules for Installation into Open Channels (WEDECO-Ideal Horizons, 2003)

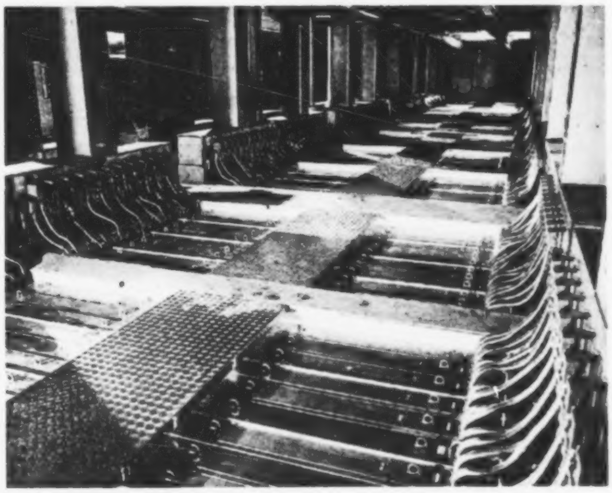


Figure 4.16 TAK UV Disinfection System in Parallel Open Channels (WEDECO-Ideal Horizons, 2003)

All TAK systems are equipped with integrated PLC systems and local operator controls, permitting local or remote monitoring (e.g., by connection to a SCADA system if desired) for fully automated operations. Based on the reported characteristics of long lamp life, ballast reliability, superior lamp module construction, effective wiping system and ease of access to all system components, the TAK systems are considered to be easy to maintain and operate.

The TAK series systems offer a number of standard advanced technical features, including:

- Advanced control system to permit "true dose pacing" by automatically and continually adjusting lamp output (i.e., can be ramped between 50 and 100% of maximum power) based on measurements of UV intensity within the system and wastewater flow rate.

- Automatically cleaned (with a wiping system) and reliable UV intensity sensors that are mounted within the lamp arrays, which are an integral component of the "true dose pacing" system.
- Automatic, chemical-free lamp sleeve cleaning (wiping) using a compressed air-powered system with flexible, UV-resistant Teflon wiper rings, while the disinfection system is in operation.

The "true dose pacing" is based on UV intensity measurements to accurately monitor and control the delivered UV dose. Control systems based on measurements of flow rate and wastewater UV transmittance alone would not take into account quartz sleeve transmittance and lamp output (i.e., influenced by aging and fouling) and, therefore, cannot provide accurate dose pacing. WEDECO also recommends optional on-line UV transmittance monitoring with their Hippo system.

WEDECO's portfolio also includes open channel LP/LI, closed vessel LP/HI, open channel MP/HI, and closed vessel MP/HI UV systems. According to the manufacturer, the open channel MP system has so far not shown any competitive advantage over the TAK-55.

Additional information on the TAK-55 series LP/HI UV technology is provided in a general information sheet (**Appendix A**).

A reference list of full-scale installations of WEDECO's TAK UV disinfection systems in North America is available. The list does not indicate the type of treatment employed at the respective municipal WWTPs. Based on the list, 68 systems have been installed since 1997, one of which is in Canada at the Port Burwell, Ontario WWTP (i.e., disinfection of effluent from an SBR process prior to discharge to a large exfiltration bed). The latter application is a TAK-55 system with a design capacity of 4.5 MLD and includes an automatic wiping system. The largest North American installation is a 250 MLD (66 US MGD) TAK-55 system in South Valley, Utah. Ten installations have design capacities of greater than 38 MLD (10 US MGD), some of which may represent good candidates for a possible site visit. WEDECO supplied the world's largest UV disinfection installation (1210 MLD capacity) at a municipal WWTP, located in Manukau, New Zealand.

4.3 Comparison of Different Manufacturers

Some manufacturers provide a single technology for UV disinfection while others provide multiple types of reactors and lamps for different applications. Ultra Guard provides a single type of lamp and orientation for all UV applications. This unit uses the 1620 W rated lamp with a germicidal output of 540 W. Some systems use low pressure/high intensity lamps exclusively including:

- Ultra Guard;
- Suntec *environmental*.

Aquionics uses medium pressure/high intensity lamps. ONDEO Degremont uses low pressure lamps but offers both low and high intensity output. Trojan Technologies and WEDECO offer all three types of lamps with their various systems, although WEDECO more actively markets their open channel systems with low pressure/high intensity lamps.

Table 4-2 Summary of UV Systems Manufacturers for Wastewater Disinfection

Manufacturer	Supplier (in Ontario)	Types of Systems	No. of Systems	Years Experience	Example Installations	Particulars
ONDEO Degremont	ATSI Hamilton	LP/LI, LP/HI	Over 200	10 years	Barrie, ON Delaware, OH	Vertical lamps, flow staging
Suntec *environmental*	ACI Instrumentation	LP/HI	14 installed	3 years	Deseronto, ON Georgetown, ON	Horizontal lamps; flow/dose pacing
Aquionics	Aquionics	MP/HI	About 100 in U.S.	18 years in U.S.; 70 years for two sister companies	Gainesville, GA Yellow River, GA	Closed chamber; perpendicular inline; flow-pace
WEDECO–Ideal Horizons	ENV Treatment Systems	LP/LI, LP/HI, MP/HI	68 installed in North America	25 years	Port Burwell, ON, Grandville, MI	Horizontal lamps; flow/dose-pacing
Trojan Technologies	H2Flow Equipment	LP/LI, LP/HI, MP/HI	Over 2000	25 years	London, ON Sarnia, ON	Horizontal lamps; flow/dose pacing for HI systems
UV Systems Technology Inc. /Ultra Guard*	US Filter/Wallace & Tiernan	LP/HI	<10	6 years	Deep River, ON	Vertical single lamp reactors; flow/dose pacing

* UV Systems Technology has recently given the rights to manufacture the Ultra Guard UV product line to BCA the Clearwater Group, British Columbia; USFilter markets and supplies the product line in North America

Notes:
LP, LI, HI, MP refer to low pressure, low intensity, high intensity and medium pressure, respectively.

Table 4-2 summarizes the various systems available from each manufacturer and indicates the supplier, number of installations, years of experience and other comments. The figures are current as of March 2002. Trojan Technologies has the most installations, especially in North America. Both Trojan and WEDECO have many installations worldwide and the most experience in UV disinfection. Aquionics and ONDEO Degremont have considerable experience as well. Suntec *environmental* and Ultra Guard are relatively new and have few installations, but provide innovative systems and have experienced personnel.

Trojan Technologies has systems for review all over Ontario. Most other manufacturers have significantly fewer installations in Ontario. All six manufacturers have systems available in North America. Many systems are planned in Ontario and North America in the next year including a retrofitted installation by Suntec *environmental* for Georgetown.

4.4 Evaluation of UV Sites in Southern Ontario

4.4.1 Overview

A number of plants were contacted and/or visited to review UV manufacturers and installations. A compromise between what the Steering Committee wanted to see and what was available led to site visits to six sites that provided information on five UV manufacturers. UV manufacturers' equipment seen during these site visits included; Trojan (Systems UV4000 and UV3000*Plus*), WEDECO, Suntec, Ultra Guard and an early Degremont type design (actually system design purchased by Degremont).

The site visits provided useful information for consideration when installing these UV systems. Additional information was also obtained from Hydromantis visits and discussions with Collingwood, ON; Delaware, OH; Port Burwell, ON; and Preston/Cambridge, ON. Some of the main areas for consideration, raised during the visits, include:

- Impact of algae on systems
- Need for shelter over units
- Access to modules
- Out of channel cleaning needs
- Spare equipment needs

4.4.2 Background

As part of the UV Windsor Feasibility and Guidance Manual project, a number of plants were visited to review installations, operational issues and manufacturers for UV equipment. Three tours were conducted involving a total of six wastewater treatment plants. These sites included:

- Sarnia, Oxford/London and Trojan Technologies head office and R&D facility (Tour 1)
- Grandville MI (Tour 2)
- Deseronto, Peterborough and Georgetown (Tour 3)

In addition, two plants were visited by Hydromantis staff and two others were phone interviewed. **Table 4-3** summarizes the plants involved, tour dates (or contact dates), plant size, type of UV equipment and installation date of equipment.

A standard form was used to summarize information for the main six plants toured. To assist in the tours, the form was sent to plant staff prior to our visits.

The ideal goals of the tours were to visit sites that were:

- Greater than or equal in size to Plant No. 1 at Little River (36.4 MLD average design flow)
- Operating in winter
- Operating greater than 1 year
- High intensity UV lamp sites

Table 4-3 Sites Visited or Contacted Concerning UV Installations

Plant	Tour	Plant Avg. Flow (MLD)	Type of UV Equipment	Installation Date
Sarnia, ON	Feb 14, 2002	38.7	Trojan UV4000	Spring 2001
Oxford/London, ON	Feb 14, 2002	6/10	Trojan UV3000'	Feb 2000
Grandville, MI	Feb 22, 2002	16.5	WEDECO	Feb 2002
Deseronto, ON	Mar 5, 2002	1/5.5	Suntec *environ.*	Nov 2000
Peterborough, ON	Mar 6, 2002	47.5/60	Ultra Guard	Feb 2002
Georgetown, ON	Mar 6, 2002	16/22.7	Suntec/Degremont	2002/1989
Collingwood, ON	Nov 14, 2001	16.3/24.5	Trojan UV4000	1998
Preston/ Cambridge, ON	Jan 9, 2002	13.5/45	Trojan UV4000	July 2000
Port Burwell, ON	Call Mar 2002	0.5/1.4	WEDECO	Feb 2001
County of Delaware, OH	Call Jan 2002	38/23 (2 plants)	Degremont	2001/1999

Not all these criteria could be realized due to the mainly seasonal disinfection practiced in Ontario, lack of sites for some manufacturers and distance to some site locations. Sites determined and subsequently visited were a compromise, but resulted in five of the manufacturers' sites being toured. The pre-Degremont system that was viewed was not the newest technology and is being replaced. Two types of Trojan systems were also visited included the medium-pressure/high intensity Trojan System UV4000 and the low pressure/high intensity Trojan UV3000*Plus*.

All systems were operating during the site visits conducted for this project.

Trip reports for each site visited are provided in **Appendix B**, including notes from a tour of Trojan Technologies head office and R&D facility in London, ON. Phone conversation summaries are also attached for Port Burwell, ON and Delaware, OH as well as a small site visit report for Collingwood and photos of the Preston (Cambridge) system. Information for each site includes contact information, plant performance and design, UV equipment and notes. Photos are provided for each site. Some sites provided additional information including:

- **Sarnia** – Earthtech provided information on costs and sections from the pre-selection document
- **Grandville** – Provided cost breakdown for installation
- **Peterborough** – Provided presentation slides, Relative Lamp Ratios of Competing UV Systems, Technical Memorandum: UV Disinfection – Ultra Guard
- **Georgetown** – Part of UV Specifications

Materials are appended from the minor site visits by Hydromantis staff (Collingwood and Preston) and phone conversations (Delaware OH and Port Burwell). Main items from this work include:

Collingwood – Good performance and maintenance noted, winter storage issues raised in past but corrected. Cost of lamps high but obtaining expected life. No cover for units, but seasonal operation and control panel in adjacent building.

Preston/Cambridge – New Trojan System UV4000 installation with staggered lamps (2 rows of staggered lamps). Observed lamp replacement and cleaning procedures. Replacement of lamps seemed straightforward, although cold work due to outside location and weather. Lamp replacement was planned activity.

Delaware, OH – High intensity Degremont installations at two plants. Good operating experience, older system from 1997, newer installed in 2001.

Overall, most plants are satisfied with the UV equipment at their plants. The systems are meeting the disinfection needs, and generally exceeding them. Maintenance does not seem to be a big issue with new systems, although operating experience is generally not long. The Georgetown WWTP existing system is considered a high maintenance item but this system is older (1989) and is a low intensity system with many lamps. Although it is being replaced, it has met the plant's needs in the past. Some initial discussion points that were raised from the tours and/or discussions include:

Impact of algae on most systems may be a concern. Tours were held in winter, but many systems seem to have areas that will catch algae and cause problems, such as open tankage upstream of UV (Grandville), wires or pipes at the headend of lamps (WEDECO, Suntec and to lesser extent Trojan System UV3000*Plus*), and upstream screening (Ultra Guard). It is a concern that lamp wipers are not expected to be able to effectively remove algae. Wipers on the Trojan System UV4000 did seem to keep lamps clean at Sarnia, but algae did form off of lamp and might cause some interference when in service.

System enclosures are recommended. A number of systems are completely outdoors, including Sarnia, Oxford, and Grandville. Sarnia and Grandville indicated they will be investigating covering the UV systems in the future to provide shelter for working on system. Shelters would also make it easier to access control panels and view screens. Viewing the control screens was a problem at all three locations. Deseronto, Peterborough and Georgetown UV facilities are all completely enclosed in buildings.

Ease of access to UV modules. All systems are located below grates that need to be removed prior to accessing UV modules. Most systems have hoisting equipment to assist in removing modules or banks. Deseronto had a cart to hold the UV modules when out of the channel. The Grandville system had a wash tank available. The Trojan System UV4000 unit has an incorporated winch system to access modules that is very useable. The Ultra Guard system at Peterborough has a power winch/crane for removing lamp units, but to keep the unit stable the reactor must stay partially in the channel. Working on a module above the channel would appear too awkward and a potential safety concern.

Out of channel cleaning. The need to remove UV modules and lamps for inspection, cleaning, and lamp replacement should be considered for any installation. The need to provide out of channel cleaning probably depends on the site, but suppliers seem to vary in terms of the need. At Grandville, WEDECO was required to provide an external wash tank, but it appears that they would not normally feel this is required. The existing system at Georgetown provided an alternate concept for acid cleaning. This system was able to be isolated in the channel and the modules could be acid cleaned *in-situ*.

Spare equipment needs and storage. Spare equipment is generally maintained at most sites. The amount of spares maintained seems to vary from site to site. Deseronto and Grandville appear to maintain a complete backup module and some additional items. Georgetown intends to base their spares on a percentage of the equipment in service and for lamps, ballasts and quartz sleeves the plant will maintain spares for 25% of the installed equipment. Sarnia seems to be storing used lamps, with greater than 5,000 hours of life, as emergency backup units. Grandville was told that maintaining too many spares might be a problem due to lamp "shelf-life".

Some initial discussion points, in terms of the advantages and disadvantages for each main installation visited, are provided in **Table 4-4**.

Table 4-4 Initial Advantages and Disadvantages List for Main Plants Visited

Plant (System)	Advantages Noted	Disadvantages Noted
Sarnia, ON (Trojan)	• Good access to lamps • Small number of lamps	• Lack of shelter for system and viewing of controls • Safety of working on lamps over open channel
Oxford/London, ON (Trojan)	• Similar installation to Windsor, easy retrofit from Trojan UV2000	• Lack of shelter for system and viewing of controls
Grandville, MI (WEDECO)	• Very professional installation, panel design etc.	• Extras need to be accounted for in design for control gate, level indicators, transformer and HVAC for panel • Impact of upstream tank and lamp wires etc. on algae
Deseronto, ON (Suntec *environ.*)	• Uniqueness of submerged lamp ballast in line with lamp	• Lack of control used • Weir level fluctuations
Peterborough, ON (Ultra Guard)	• Unique system design with high output lamps • Small number of lamps	• Limited full scale experience with process and control system • Complexity of system in terms of fans, cleaning solution etc.
Georgetown, ON (Suntec *environ.*)	• Channel design with isolation	• Age of existing equipment and large number of lamps

5 Planning and Design Considerations for UV Disinfection Applications

This chapter outlines and discusses important considerations related to the preliminary assessment, planning, and design of UV disinfection applications. This pertains to full-scale projects involving UV facility installations as part of either a new or existing WWTP or the retrofitting of an existing disinfection facility.

The most appropriate UV disinfection process technology and design for a particular application is site-specific. Important factors for consideration can include physical layout of the site, wastewater characteristics, disinfection requirements, WWTP process design and operation, UV system design and operational preferences and strategies, and available resources. These factors will be described and addressed in **Chapters 5 and 6**.

This chapter focuses mainly on UV applications that involve disinfection of secondary treated effluent generated by suspended growth biological treatment processes (i.e., activated sludge process and its variations), with or without tertiary filtration. Disinfection of effluents from lagoon systems or fixed-film secondary treatment processes is not covered in detail.

Secondary treated quality effluents typically have UV transmittance (UVT) levels and total suspended solids (TSS) concentrations of between 45 to 75% and less than 10 to 30 mg/L, respectively. UVT levels for activated sludge process effluent, in particular, are reportedly from 50 to 75% and typically about 65%. UV transmittance levels in effluents from attached growth and lagoon-based biological treatment processes are typically lower than for activated sludge process effluents. Tertiary treated effluents (i.e., conventional sand-filtered secondary effluents) have improved characteristics of 60 to 80% UVT and less than 5 to 10 mg/L TSS, which facilitates UV disinfection. Higher degrees of filtration such as by microfiltration or reverse osmosis can eliminate TSS and further increase UVT (Metcalf & Eddy, 2003) that can further facilitate UV disinfection.

5.1 Application Assessment and Facility Planning

There are a number of considerations involved in the assessment of new UV disinfection applications and the development of preliminary site-specific plans and system selection and design. These include site characteristics, disinfection requirements, information needs, and the pre-selection of suitable UV processes.

5.1.1 Site Characteristics

Various possible scenarios exist for the application of UV technology for disinfection of municipal wastewaters, some of which are listed below.

- UV disinfection system as part of:
  - a "Greenfield" WWTP
  - a new installation at an existing WWTP
  - a retrofit of an existing disinfection system

- Degree of variability of raw sewage flow rate
  - seasonal and daily variability
- Level of treatment of the influent wastewater (i.e., primary, secondary, or tertiary treated effluent)
  - degree and consistency of secondary treatment
- Type of upstream secondary treatment process
  - traditional activated sludge processes (ASP)
  - alternative ASPs (e.g., membrane bioreactor, sequencing batch reactor, etc.)
  - attached-growth processes (e.g., trickling filter, rotating biological contactor, biological aerated filter, moving bed biofilm reactor, fluidized bed, etc.)
  - hybrid processes (e.g., trickling filter/solids contact, integrated fixed film activated sludge, etc.)
  - aerobic lagoon processes (e.g., continuous-flow or seasonal discharge aerated lagoon or facultative lagoon)
- Type of chemical addition(s) at upstream process stages (e.g., for chemical precipitation of phosphorus)
  - alum versus iron salts
  - polymers
- Industrial effluent component of the WWTP influent wastewater
  - associated impacts on UVT
  - variability of discharges (e.g., from batch manufacturing operations)
  - seasonal influences
- Potential for increases in future WWTP influent loading (i.e., flow rate and contaminant mass loading)

5.1.2 Disinfection Requirements

The effluent discharge quality criteria for a particular municipal wastewater treatment application must be defined. Target disinfection levels used for design purposes will be more stringent than the regulated discharge requirements. Based on this information, together with actual or predicted characteristics of the influent wastewater to the disinfection stage, the UV system requirements (i.e. design UV dose) can be determined. The disinfection requirement will determine the size of the UV system (i.e., number of lamps; depends on lamp intensity) and whether UV irradiation will achieve the target disinfection levels.

Information on wastewater characteristics and from bioassay testing results is used to determine the UV dose demand of an effluent for design purposes, as discussed in **Section 5.1.3**. Various other factors for consideration in system requirements and design are described in **Section 5.2**.

5.1.3 Information Needs

Initial characterization information is required to assess the applicability of UV technology and to serve as a basis for process selection and disinfection system design. This information can help to determine the optimum design dose requirements of the UV disinfection system for a particular application and to establish appropriate design safety factors and operational strategies.

The performance of UV disinfection depends on such wastewater characteristics as UV transmittance, suspended solids concentration, the size and nature of particulates, and the presence of constituents that can foul or precipitate on the lamp sleeve. Relevant characterization information on the candidate influent wastewater that should be obtained and assessed includes:

- Flow (i.e., average, minimum, and maximum rates and the degree of variability)
- Composition (i.e., average, minimum, maximum levels and degree of variability) of various important parameters such as:
  - UV Transmittance
  - TSS (concentration and nature of the particulate or colloidal matter)
  - particle size (mean value and distribution)
  - fecal coliform (or other pathogenic indicator organisms) levels
  - hardness and alkalinity
  - iron
  - dissolved inorganics
  - pH
  - temperature
- Degree of upstream wastewater treatment (e.g., primary, secondary, or tertiary treatment)
- Industrial wastewater contribution to the WWTP influent
  - sources and nature of the industrial effluent component
  - relative contribution to WWTP influent flow and composition
  - variability (e.g., daily, weekly, seasonal contributions)

Flow rate (i.e., peak levels), UV transmittance (UVT), and TSS concentration are the principle influent wastewater parameters that determine the size and design of a UV disinfection system. As wastewater UVT decreases (i.e., absorbance increases), the average UV intensity within the UV reactor decreases. Accordingly, more UV energy is required in order to achieve the desired UV dose to meet disinfection targets. Should there also be a change in the quantity and characteristics of suspended solids (e.g., particulate size), the UV dose requirement may become different due to the shielding effect.

UVT is influenced by the presence of soluble substances that absorb UV as well as particulates that can absorb or scatter UV irradiation. This includes certain soluble or colloidal organic constituents, background colour, iron, suspended solids, etc. The nature of soluble organic constituents is important with regard to impacts on filtered UVT. For example, the industrial wastewater component to the municipal WWTP may have a significant impact on the wastewater's UVT.

The presence of suspended solids can negatively affect UV disinfection by a number of mechanisms, namely UV light scattering, shading, and incomplete penetration of particles containing imbedded pathogenic microorganisms, as described in **Section 3.2.3.2**. The concentration of TSS and the size of particulates can therefore impact UV dose requirements. If large particles are present, embedded microorganisms will not be inactivated by conventional UV processes and dosages. Various devices (i.e., particle counters) are available for the determination of average particle size and particle size distribution as part of the characterization of the candidate wastewater (WERF, 1995).

Another important issue and consideration for UV disinfection is the potential for scaling and fouling of the lamp sleeve which will reduce the average UV intensity in the wastewater and thus impact the dose delivery capability of the UV reactor. The potential rate of fouling will determine cleaning requirements. A fouling safety factor must be applied for design purposes.

Fouling of the external surface of lamp sleeves and UV intensity sensors may be caused by precipitation of certain inorganic compounds, deposition of organic compounds (e.g., fats, oils and grease and colloidal matter) and particulates, and biological growth. Precipitation depends on wastewater composition (i.e., alkalinity, hardness, calcium, magnesium, and iron concentrations), temperature, and pH, which should be measured for characterization. Biological growth occurs when the wastewater remains in the UV system while the system is not in operation, which may happen periodically (WERF, 1995).

The facility designer must analyze and assess the required site-specific information, including wastewater characterization data. This will form part of the basis for system design (e.g., appropriate UV dose). Adequate characterization data is especially important for less established applications (e.g., UV disinfection of non-activated sludge based treated effluents).

5.1.3.1 Characterization of UV Transmittance

It is recommended that sufficient field UVT measurements (i.e., at 254 nm) be performed on representative samples of the candidate wastewater. The following are considerations related to wastewater sampling and UVT measurements.

- Grab samples taken at a specific time and location are preferred over the collection of composite or blended samples taken over a given period of time
    - on-line continuous UVT monitoring is another option
- Certain suppliers suggest that a minimum of two grab samples per day (i.e., such as at peak and low flow conditions) over a two week period can provide the necessary minimum UVT characterization data

- An automatic 24-hour discrete sampler could be set up for one week and UVT tested on each sample to determine and characterize the effects of possible batch or off-hours industrial releases
- Seasonal variations in UVT characteristics may have to be given consideration
    - stormwater inflows and industrial discharges can lead to seasonal variations in UVT (Metcalf & Eddy, 2003)
    - this would require longer term assessments of UVT
- At-source effluent sampling and measurements of UVT for all major industrial contributors could be considered
- In addition to unfiltered UVT, the measurement of UVT on filtered samples can provide additional useful information
    - relative influence of suspended particulates on UV transmission may be estimated
    - samples may be filtered through 0.45 micron membranes; no standard protocol exists for determination of filtered UVT (WERF, 1995)
- In addition to UV transmittance measurements at 254 nm, UV scans can be used for determining polychromatic effects

5.1.3.2 Collimated Beam Testing

To complement the characterization of influent wastewater, including UVT (i.e., typical levels and the degree of variability), collimated beam testing with representative wastewater samples can be used to produce a dose-response relationship (i.e., measured log inactivation of an indicator microorganism versus UV dose). The collimated beam test is conducted under controlled conditions of exposure time, mixing, and UV intensity. The UV dose response data generated by collimated beam testing with representative wastewater samples can be used to establish the UV dose required to achieve a target level of disinfection. As indicated above, the UV dose demand will be affected by factors such as the degree of wastewater secondary treatment, TSS concentration, and the presence of constituents that absorb UV. Therefore, to be used for design purposes, the collimated beam test results need to be adjusted for these factors as well as full-scale reactor hydraulics.

The bench scale collimated beam devices are used to provide precise doses of UV radiation to a mixed sample. The fluence rate from a monochromatic source (i.e., low-pressure lamp emitting at 254 nm) is usually measured with a calibrated radiometer. Upon completion of UV irradiation, the sample is immediately analyzed for microbiological characteristics (i.e., indicator parameters) to determine the level of inactivation (i.e., based on the enumeration of the selected parameter before and after irradiation). **Figure 5.1** shows a picture of a collimated beam apparatus. Wastewater characterization data for UVT and TSS can be used to select the most appropriate time to collect representative samples of wastewater for the dose response test (i.e., to ensure that the tested samples are representative).

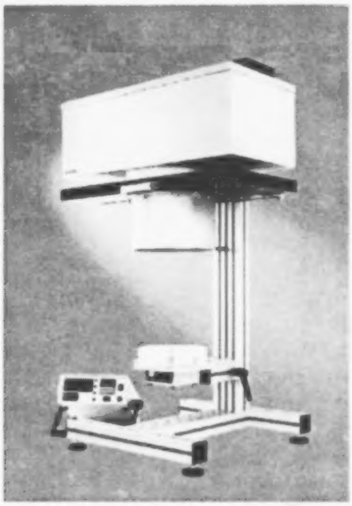


Figure 5.1 Collimated Beam Device (WEDECO-Ideal Horizons, 2003)

Unlike in a collimated beam device, the actual UV dose cannot be determined exactly in a flow-through reactor since the UV intensity and exposure time cannot be precisely known. Accordingly, performance based validation procedures using bioassays have been developed to determine delivered UV dose. These procedures provide confidence to the design consultant and the prospective owner that the UV system will perform as specified. A discussion on the validation of UV reactors using bioassay procedures is described in **Section 6.3.2**.

5.1.4 Process Pre-selection

There are numerous manufacturers offering a variety of unique technologies and process configurations, as described in **Chapter 4**. Detailed information on preliminary process screening and selection is provided in **Chapter 6**, including process-specific features and a discussion of various important factors for consideration. The latter factors can relate to design, operation and maintenance (O&M), and cost aspects, and are usually site-specific. **Chapter 7** will outline important information requirements that should be included in quotations from suppliers of UV disinfection systems. It will also summarize preliminary capital and operating cost estimates that have been obtained from the major suppliers based on generic conditions that were provided.

5.2 UV Disinfection System Design Considerations

UV dose (i.e., fluence) is the most important design parameter, and is a function of the average UV intensity and the time of exposure of wastewater to irradiation. Average UV dose, which determines the effectiveness of a UV disinfection system, depends on:

- Wastewater characteristics (i.e., as described in **Section 5.1**), especially parameters that influence UVT,
- Reactor UV lamp output and lamp density
  - ➢ impacts average intensity

- Reactor configuration
    - hydraulic characteristics
    - spatial relationship of the lamps to the reactor chamber
    - spacing of lamps
- Residence time (i.e., exposure time) of wastewater in the reactor

It is important to accurately define the characteristics of the influent wastewater that will be used as a basis for the UV system design and performance requirements. This will also help to determine appropriate safety factors on the design.

5.2.1 Site Layout and Requirements

The design and configuration of a UV disinfection system must take into account the physical layout of the "greenfield" or existing plant to ensure proper integration. This applies to both the installation of a new UV disinfection system or the retrofitting of an existing disinfection facility.

5.2.1.1 Site and System Layout

The UV system is typically located at the end of the liquid train of a municipal WWTP, just prior to wastewater discharge. Depending on the process type, the UV reactors are either placed in open channels or in pipes through which the wastewater flow is conveyed by gravity or pumping. Most wastewater UV disinfection installations use open-channel configurations with modular designs that use either horizontal or vertical lamp arrangements. In the open channel configuration, horizontal lamps are arranged in parallel to wastewater flow while vertical lamps are placed perpendicular to flow. The alternative in-pipe systems comprise horizontal lamps arranged perpendicular to flow.

UV systems are usually designed with reactors in series and/or parallel for redundancy and flexibility to accommodate varying flow rates, lamp bank failures and required maintenance, channel cleaning, and manual lamp cleaning (see **Section 3.3.7** for more details on redundancy).

Potential future expansion should be considered in the layout of the UV disinfection system. The design should include flexibility to facilitate expansion. This is generally easy to accommodate, as UV systems are modular in design, with the ability to provide additional parallel channels or pipes. Alternatively, bulkheads can be installed within lamp banks and then removed and replaced with lamp modules when it becomes necessary.

The following aspects should be considered when planning the UV system layout:

- The size and number of UV reactors (i.e., lamp banks)
    - series and/or parallel arrangement of lamp banks
    - each parallel channel typically contains two or more banks in series
    - banks comprise specified number of modules (or racks of UV lamps)
    - modules comprise a specified number of lamps

- The total number of lamps and their configuration will depend on the modularity of the system and hydraulic considerations
  - actual number of lamps installed will usually be greater than the theoretical number required
- Provision for flexibility and redundancy in UV system designs
  - number of parallel channels or pipes
  - allows for channel or pipe isolation
  - increased number of channels or pipes reduces velocity and, therefore, also limits headloss
- Easy accessibility for inspection, maintenance, and replacement of lamps
- Space to remove lamps or lamp modules and associated cleaning mechanisms, where applicable
- Adequate space and facilities for external maintenance and cleaning of lamp modules
- Mechanical devices for the removal and moving of lamp modules, where applicable
- The required minimum length of straight-run flow conduit before and after each UV reactor
  - applies to the length of pipe or channel upstream and downstream of each bank of lamps
  - in open channel systems, inlet and outlet structures should be a minimum 2 m from the closest lamp array and the inlet flow should be evenly distributed across the array of lamps (see **Section 3.3.4** for discussion); inlet distance can be shortened by the integration of baffle plates
  - sufficient distances must be provided between lamp banks (i.e., 1.2 m for horizontal lamp and 0.3 m for vertical lamp arrangements)
- For in-line reactors, certain required minimum pipe lengths between lamps and structures apply
  - minimum length of straight pipe of 5 to 10 times the pipe diameter of an in-line reactor before the inlet isolation valve
  - minimum length of straight pipe of 3 to 5 times the pipe diameter of an in-line reactor after the downstream isolation valve or any fittings
  - lateral piping diameter should be the same as the reactor diameter for in-line reactors
- Influent velocities ranging from 5 to 50 cm/s and a maximum headloss of 10 cm are generally considered to be acceptable for open channel UV disinfection systems
  - some manufacturers suggest that the headloss across the UV banks/modules of open channel gravity-flow systems should not exceed 5 cm; this does not include the headloss contribution by the inlet baffle plate and the downstream level control system

- Proper wastewater flow splitting between parallel channels or pipes
    - require an even flow split regardless of the flow rate and the number of UV reactors on-line
- Appropriate piping and valve configurations
- Location of isolation gates or valves
- Design for ability to completely and rapidly drain channels for maintenance
- Instrumentation, with integration into plant SCADA systems, if applicable
- System controls, power panels and required clearance
- Buildings or covers over certain system components
- A bypass should be constructed around the UV disinfection system particularly for plants which require only seasonal disinfection

These considerations apply for the planning of new installations or the retrofitting of existing facilities.

For secondary treated effluent disinfection applications, there may be potential difficulties with algal growth in upstream process stages (e.g., secondary clarifiers, contact chambers, open conduits, etc.). This algal growth can periodically break off and enter the UV stage where it can become attached and accumulate at the front end of the UV system. To minimize the potential for algal growth and associated difficulties for the UV process, consideration could be given to covering these upstream areas to reduce exposure to sunlight. Alternatively, periodic cleaning with air or high pressure water can be used to clear this material.

Other miscellaneous considerations pertaining to UV system designs are outlined in **Section 5.2.2.2**, according to various categories such as design UV dose, UV lamps, system hydraulics, automatic monitoring and control, operation and maintenance requirements, pilot plant testing, and other miscellaneous factors.

Useful UV disinfection system design examples are provided in Darby *et al.* (1995). These examples pertain to a LP/LI system for disinfection of activated sludge process effluent. The system configuration involves horizontal lamps arranged in parallel to flow in parallel open channels. Various scenarios in terms of influent and disinfected effluent quality are covered.

5.2.2 Key Design Aspects

In this section, specific design and operational considerations associated with the different processes, configurations and control systems are outlined.

The critical UV process design parameters and considerations are:

- Wastewater characteristics

  - dependence on WWTP raw sewage composition, the level of treatment and effectiveness of WWTP process stages upstream of the disinfection process, and the possibility of flow bypasses
  - flow rate
- UV intensity
  - depends on UV lamp output, lamp arrangement and density, and energy sinks
- Reactor hydraulics
  - process specific
  - must ensure uniformity of flow rate and proper liquid level (i.e., for open channel systems)
  - should minimize turbulence yet ensure adequate radial mixing and no flow short-circuiting or dead zones
  - lamp spacing
  - proper distances between banks of lamps
  - effective volume

The total number of lamps and banks of lamps (i.e., reactors), and the configuration of the UV system will depend on the lamp and process type, range of wastewater flow rates, required degree of redundancy, degree of process automation, and the control strategy selected.

UV systems should be designed on the basis of maximum design flow rate (i.e., peak flow conditions). Design of UV systems should also give consideration to the desired degree of redundancy and process flexibility for a given application (see **Section 3.3.7** for more details on redundancy). Flow distributions depending on various system configurations and operational scenarios should be evaluated. Flow rate through individual UV reactors must be known and controlled to ensure proper treatment.

Proper control of suspended solids and colloidal (e.g., floatables) concentration in secondary treated effluents is necessary for ensuring effectiveness of downstream UV disinfection. Tertiary treatment offers enhanced control of these contaminants and results in improved disinfection performance (i.e., increased consistency and reduced dose requirements and design safety factor). As the level upstream of upstream treatment is increased (e.g. from primary to secondary), the performance of the UV disinfection system is enhanced. This is due to lower suspended solids concentrations, higher UVT levels, and possibly less fouling. Membrane filtered secondary effluents have potentially higher UVT and lower TSS levels than tertiary effluents from conventional sand filtration processes, thus facilitating UV disinfection somewhat (i.e., reduced dose demand).

Automatic cleaning systems are available on certain systems (i.e., with LP/HI and MP/HI technologies) for the removal of organic and inorganic fouling that can buildup on the surfaces of the quartz sleeves covering the UV lamps.

5.2.2.1 Design Criteria

Design criteria for UV disinfection systems are usually based on the following parameters:

- Design flow
  - peak hourly
  - peak day
  - maximum week
  - maximum month
  - average day
  - minimum day
- UVT (% at 254 nm)
  - minimum
  - minimum day
  - average day
- TSS concentration
  - maximum
  - maximum day
  - average day
- *Escherichia coli (E. coli)*, fecal coliforms, and/or other indicator organism for regulatory compliance; (initial density as well as target levels for the disinfected effluent)
  - maximum 30-day geometric mean (design target and non-compliance levels)
  - maximum day (for some discharge permits)
- Iron concentration
  - maximum day
- Temperature
  - minimum
  - maximum

5.2.2.2 Miscellaneous Design Considerations

Some additional aspects for consideration in UV system design are described below under various categories.

Design UV dose requirements

The UV reactor system should be sized (i.e., total number of lamps) to deliver the design minimum dose at the most conservative defined process conditions (e.g., peak wastewater flow rate, with lamps operating at the defined end-of-life germicidal output levels, minimum wastewater UVT, aged lamp sleeve transmittance level, maximum TSS concentration, least favourable wastewater temperature, etc.). Reduction factors for lamp aging, sleeve transmittance, and a safety factor are applied in system sizing.

Wastewater characteristics can have a major impact on the effectiveness of UV disinfection. Proper operation of upstream treatment process stages can maximize performance of the disinfection stage. The sensitivity of UV disinfection on wastewater quality increases as target coliform counts decrease (i.e., are more stringent) (WERF, 1995).

UV intensity depends on lamp type, lamp placement and the spatial relationship of the lamps to the chamber or channel, lamp age, quartz sleeve age, and degree of sleeve fouling. Control options include regular replacement of lamps, and manual and/or automatic cleaning of lamp sleeves.

UV dose requirement and system sizing for the disinfection (i.e., fecal coliforms limit of less than 200 MPN per 100 mL) of secondary treated quality effluent from activated sludge processes is typically greater than 30 mJ/cm^2. Attached growth processes such as trickling filters and rotating biological contactors may require a higher UV dose. Tertiary filtered activated sludge process effluent typically requires a somewhat reduced UV dose of greater than 20 mJ/cm^2 for adequate disinfection as the UVT is typically higher and the TSS is lower.

UV lamps

UV lamp description and specifications from the system manufacturer should include the following information:

- Lamp category (i.e., LP/LI, LP/HI, or MP/HI)
- Rated lamp wattage
- Lamp dimension (i.e., arc length and diameter)
- Total electrical power input including lamp and ballast
- UV output at 254 nm
- Manufacturers that produce the particular lamp
- Dimensions of the quartz sleeve (i.e., diameter and wall thickness)

Effective lamp life is defined as the number of hours of operation until the lamp output at 254 nm drops to 70% of the output of a new lamp that has been burned in with 100 hours of operation.

UV system hydraulics

A hydraulic analysis of the WWTP and proposed disinfection facility should be conducted for the determination of hydraulic limitations, requirements and associated considerations.

Hydraulic properties of the UV reactor are dependent on reactor design as well as inlet and outlet structure designs and components. Minimum threshold distances are required upstream and downstream of bank arrangements as well as between lamp banks in series. Baffles or diffusers may be employed to assure that proper mixing occurs and to minimize any short-circuiting of the wastewater flow. Minimum thresholds for required straight pipe lengths should be provided for in-pipe reactors. For in-pipe reactors, lateral piping diameter should be the same as the reactor diameter. In open channel systems, inlet and outlet structures should be a minimum 2 m from the closest lamp array and the cross section of the flow into the array should be evenly distributed. The inlet distance can be shortened by the integration of baffle plates. See **Section 3.3.4** for additional discussion.

Proper hydraulic design is critical to ensure even flow distribution between multiple parallel reactors/channels while minimizing overall headloss. This may be dependent on wastewater flow rates. At lower velocities, there is less turbulence and a resulting decrease in reactor efficiency.

The flow rate per lamp determined by UV system validation testing has a corresponding velocity that maintains the inactivation performance. The process configuration must therefore maintain adequate system velocity to ensure that the bioassay results are applicable to the full-scale field installation (Metcalf & Eddy, 2003).

The actual headloss for a disinfection facility is application-specific, and dependent on reactor design as well as associated piping and fittings. Headloss created by the UV system is a function of the inlet liquid velocity and the reactor geometry.

Headloss through the UV disinfection system is an important consideration especially in the case of retrofit applications. There may be hydraulic constraints at the plant and these will have a significant potential influence on the suitability of alternative UV retrofit equipment. It may be necessary to introduce structural modifications and possible effluent pumping to overcome excessive headloss through the UV system. The LP/LI and LP/HI open-channel processes generally have low-to-moderate headloss across a bank of lamps. The head loss through MP/HI systems can vary from several inches to a few feet per bank of lamps, depending on the flow rate. Site-specific cases involving elevated headloss may require wastewater pumping. Headloss through the entire channel also needs to be considered (i.e., across valves, baffle plate, UV reactor, and level control system).

UV reactors must be continually flooded during operation to avoid overheating and UV light exposure (i.e., for safety). In the case of open channel systems, it is critical that liquid level be controlled to narrow variances over a broad range of influent flow rates. Inadequate reactor liquid levels can result in exposure of lamps and resultant overheating and fouling. Excessive liquid levels can result in inadequate irradiation and disinfection of the flow.

A variety of level control devices are available, the suitability of which depends on the maximum and range of flow rates for the application. Level control gates, either automatically actuated or weighted, are preferred for elevated flow rates in open channel systems, while weirs are suited for lower flow rates. Weirs are simple devices without mechanical moving components. There is no risk of channel draining during low flow conditions with weirs. **Photo 5-1** shows a weighted gate, **Photo 5-2** shows an actuated gate, and **Photo 5-3** shows an extended weir level control device.

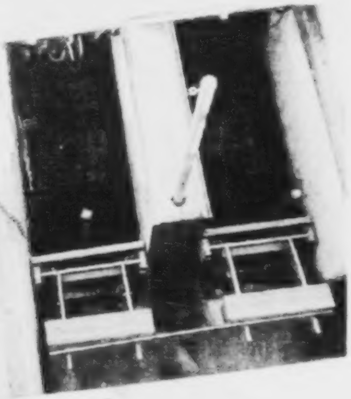


Photo 5-1 Weighted Weir Level Control System

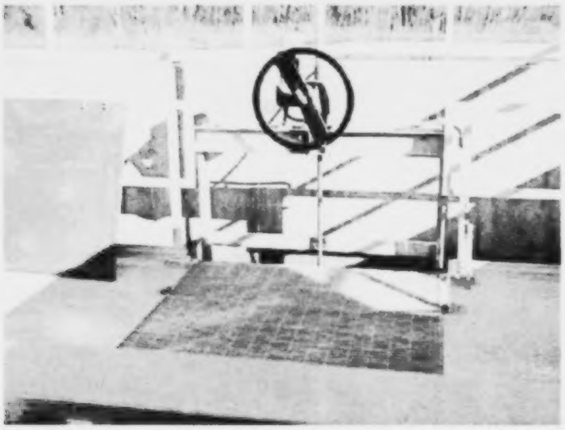


Photo 5-2 Motor Actuated Level Control Gate

Photo 5-3 Extended Weir Level Control

Automatic monitoring and control systems

The UV control system can range from manual to highly automated. The main functions of automatic control systems are:

- To maintain an adequate UV dose while conserving energy and lamp life
- To shut off modules when lamps are exposed to air or if the temperature in the reactor chamber becomes too high
- To control any automatic cleaning system mechanisms

Automated control systems may be microprocessor based or PLC based. The requirement for a PLC-based control system depends on a number of factors including system size, the number of channels and lamp banks, and the interface to WWTP distributed control system (DCS).

Additional details are provided in **Section 3.3.6**.

Instrumentation and control

On-line measurements of wastewater flow rate are typically used as a basis for UV process control (i.e., flow pacing). Certain UV processes are also controlled on the basis of on-line UV intensity and/or UVT measurements for dose pacing. UV intensity monitors can also confirm adequate lamp output and sleeve transmittance under actual operating conditions and can detect drops in lamp output and/or fouling effects. Reliable UV intensity sensors should be used and should be located at a suitable distance from the lamps so that the influences of lamp ageing and UV transmittance of the effluent are being measured in an equal manner. UV intensity sensors should be factory calibrated once per year or checked with a reference sensor. Regular cleaning of the sensors is necessary to minimize the effects of fouling and to maximize the accuracy of readings.

On-line monitoring, alarm, and control systems can be integrated with SCADA systems at the WWTP. Certain operational parameters require alarms and control system interlocks to safeguard the disinfection process and equipment.

O&M requirements and costs

O&M requirements are process and site-specific. Preferred operating strategies can influence process selection and system design and life cycle cost.

O&M costs are important components of a life-cycle cost assessment of alternative systems. Major O&M cost components include electrical power consumption, replacement of lamps, sleeves and ballasts, lamp cleaning, and general process and channel maintenance.

The increased complexity, capital cost and enhanced control of a highly automated process versus the simpler designs and operation but increased O&M labour requirements, down-times, and space requirements must be assessed for each application. Labour requirements for the upkeep and repair of components associated with the automated systems should be considered as well.

Pilot plant testing

Pilot plant testing is not generally required for determining the feasibility and/or design of UV disinfection technology for sites employing activated sludge secondary treatment, as there is much related information and experience for this established application. This assumes that the industrial contribution to the WWTP influent is not significant and that the secondary treated effluent UV transmission levels will be greater than 50%.

Adequate characterization of the candidate wastewater, in particular UVT measurements, together with collimated beam testing are usually sufficient for the determination of appropriate UV dose requirements and the sizing of UV disinfection systems for established applications.

Pilot plant testing of UV disinfection is recommended for cases where the contribution of industrial discharges to the sewer is high and/or for the less established applications involving attached growth or lagoon-based secondary treated effluent disinfection. The following are some additional related considerations.

- The characteristics of certain industrial wastewaters (e.g., UV light absorbing properties) can have a significant impact on the applicability of UV disinfection; absorption of UV light is not necessarily related to colour of the effluent
- Secondary treated effluents from attached growth processes will require higher UV dosages for a target treatment level compared with suspended growth process effluents due to larger particle sizes in the treated effluent; depending on disinfection requirements, tertiary filtration may be required
- Lagoon effluents may require higher UV dosages than activated sludge process effluents owing to generally higher effluent TSS (albeit with smaller particle sizes); microscopic algae present in facultative lagoons can decrease effluent UVT
- Pilot scale testing of the upstream biological processes will also be required for "greenfield" applications to generate representative effluent samples for characterization and UV disinfection testing
- Some manufacturers suggest that pilot plant testing of the less established applications need only be conducted for cases with UV transmissions of less than 50% for the candidate wastewater for disinfection
- Some manufacturers believe that pilot plant testing is not necessary prior to designing a UV disinfection system for effluent from any type of wastewater treatment process
    - this is based on long proven full scale experiences and the availability of validated bioassays which together with collimated beam studies should be enough to help establish the majority of design parameters

A detailed discussion on the benefits and aspects of pilot plant testing and demonstration of UV technology is given in **Section 6.3.3**.

Additional design and operational considerations

There are no major advantages or disadvantages between horizontal and vertical lamp configurations. Horizontal lamps can be more readily retrofitted into existing channels. Vertical lamps require deeper channels and more space requirements (e.g., for maintenance and cleaning when removed from service). Structural modifications may be required to accommodate vertical lamp systems in retrofit applications. Vertical lamp arrays offer a staggered arrangement, thus allowing for disinfection operation even if some lamps are out of service. Isolation valves are recommended upstream of individual channels to allow for flow-based control and/or to facilitate shutdown and maintenance.

Proper cleaning and maintenance is essential for effective UV disinfection performance. Cleaning of lamp sleeves (i.e., manually or automatically with mechanical wipers, with or without chemicals) can minimize the negative effects of lamp fouling. Air scouring or high pressure water spray can also be used for cleaning. The required frequency of cleaning is process and site specific. Chemical cleaning of lamp sleeves is a requirement for all UV process installations for wastewater disinfection applications. Again, the required frequency of chemical cleaning is case specific. On-line automatic cleaning systems can minimize the requirement for chemical cleaning. The installation of external cleaning stations is recommended as a safeguard for occasional external cleaning, if required. Spent cleaning solution can either be recycled or directed to the head of the WWTP for treatment. Volumes are small and environmentally friendly cleaners are available.

Substitution of phosphorus removal chemicals (e.g., use of alum instead of iron salts) is an option for reducing inorganic fouling associated with secondary treated effluents.

Equipment (e.g., lifting device) is required to facilitate the removal of lamp modules from channels (i.e., for inspection, cleaning, maintenance, and replacement) in the case of low pressure UV systems. One of the MP/HI processes is designed with a built-in module removal mechanism while the in-line MP/HI process design permits easy access to lamps.

Heat removal from ballasts is important. Some system designs with electronic ballasts rely on convection or cooling of ballasts by wastewater. Certain LP/HI and MP/HI systems require dedicated ventilation and temperature control systems for the ballasts, such as fans or heat exchangers.

UV lamps must be replaced upon failure or at the end of their expected lifetime. Generally, lamps need to be replaced when the intensity has declined to 70% of the new lamp intensity (based on clean chamber conditions). A regular lamp replacement schedule is important because lamps age due to solarization of the lamp wall and deterioration of the electrodes. As the lamps age their output decreases and this reduces the performance of the UV system. Furthermore, ballasts are usually replaced every 10 years while quartz sleeves are usually replaced every 5 years (USEPA, 1999b). One manufacturer claims that quartz sleeves for MP/HI systems last for 5 years while those for LP/LI and LP/HI lamp systems usually last for 20 years.

In order to ensure that a UV system remains in service during power failures, standby power generators are often used. Another consideration is the possible installation of a backup disinfection system (e.g., chlorination/dechlorination) that could be used temporarily in the event of UV system failure (see **Section 3.3.7** for more details on standby power and backup disinfection). Provision for manual over-ride of UV control systems could be considered to enable continued UV disinfection in the event of automatic control system failure.

Another important consideration with regard to electrical supply is that UV systems should not be powered from a motor control center that powers variable frequency drives (VFDs) because ballasts can produce harmonic distortions that may disrupt the VFDs (USEPA, 1999). This can be addressed with harmonic filters or the separation or isolation of power supply to the UV system. An assessment should be conducted during start-up of a new UV process to verify that the UV system harmonics are not affecting other electrical components at the WWTP. Electrical power transformers are required for certain UV systems.

Algae that may be present in secondary treatment process effluent can become entrapped on the upstream edge of the UV system. The build up of strands of algae can cause hydraulic backup problems and interfere with the disinfection process.

Upstream screening systems are sometimes recommended for UV systems to capture algae and debris such as plastic and leaves which may get trapped around the lamps (WEF, 1996). The cleaning of these screens may be a problem and they introduce additional headloss.

Installation of shelters to house system control panels and displays is recommended to protect equipment from outdoor ambient conditions and to provide a clean and convenient location for operations and maintenance staff to access and maintain the equipment. Shelters make it easier to access control panels and to view display and control screens. **Photo 5-4** shows a canopy structure to shelter a ballast panel and controls, while **Photo 5-5** shows a completely enclosed UV system.

Upon installation of a UV disinfection system, field verifications could be performed to determine actual system performance and capabilities (e.g., UV dosage delivered). Power draw measurements can be included in the testing. This is conducted by using collimated beam testing.

5.2.3 Detailed Listing of UV System Components

An itemized listing of the various possible components of UV disinfection systems is given below. These items may be either standard features or optional components, or not applicable, depending on the particular UV technology and application.

- UV lamps, sleeves, ballasts, and modules
    - ➤ UV lamps can be proprietary or available from a number of reliable sources
    - ➤ is available as a complete integrated reactor unit for certain systems
- Support framework for installation of the lamp modules in the channel
- Power Distribution Center (PDC)
    - ➤ one PDC for each bank of lamps

Photo 5-4 Canopy Structure Enclosure for UV System

Photo 5-5 Complete Building Enclosure for UV System

  - power supply and power panels
- Power transformers for externally mounted ballasts
- Automatic control system
  - System Control Center (SCC) that is either microprocessor or PLC-based
  - integrated into each PDC
  - local operator controls; alternatively, remote monitoring is possible
- Automatic cleaning system (ACS)
  - for lamp sleeves and UV intensity sensor (if applicable)
- Drive system for ACS

- Air conditioning systems for ballasts
    - applies only for ballasts that are contained in cabinets
- Ballast cooling system comprising a heat exchanger with a circulating coolant such as propylene glycol for certain processes
- HVAC for MCC and panel
- Inlet diffuser plate
- Influent flow control gate or valve
- Level control system for open channel configurations
- Lifting device for individual modules or banks of lamps or reactor
    - elaborate module removal mechanism for certain processes
- Sensors and instrumentation for on-line monitoring, alarm, and/or control
- Air blower and air sparge cleaning system
- Cleaning station
- Enclosures (NEMA 4X or NEMA 12)
- Spare parts
    - e.g., lamps, sleeves, end seals, ballasts

6 Screening of Alternative UV Technologies

This chapter provides a preliminary process screening procedure to facilitate the identification and selection of appropriate alternatives for different wastewater disinfection applications and scenarios, taking into consideration certain key criteria. The chapter begins with a summary of commercially available UV disinfection technologies and their respective advantages and disadvantages/limitations. This is followed by the process screening procedure, which focuses on suspended growth secondary treated effluent disinfection applications and is presented in a decision-tree format.

Various technical and non-technical site-specific factors will be outlined that should be given consideration in the development of short lists of process options and subsequent detailed system designs for a particular application. Two examples are included to demonstrate the use of the decision-tree for identifying appropriate UV process alternatives for a new facility installation and a retrofit application. The examples will also show that other important factors may come into play in the selection of the most appropriate process for a given application.

6.1 Summary of Available UV Disinfection Technologies

This section provides a summary of the advantages and disadvantages of the alternative UV disinfection technologies according to the three lamp categories (i.e., LP/LI, LP/HI, and MP/HI).

Features of the various commercially available processes were summarized in **Table 3-2**. Additional process-specific information is detailed in **Section 4.2.4** and in **Appendix A**, while a general comparison of the six main manufacturers and their respective UV processes is given in **Section 4.3**.

6.1.1 Low Pressure / Low Intensity Systems

Conventional LP/LI systems have the most widespread application for the disinfection of municipal wastewaters.

Advantages

- Simplest designs
    - installation facile en canal ouvert
    - horizontal and vertical lamp arrangements are available
    - vertical lamp systems come with an air scouring system
- Highest energy efficiency
- Long lamp life
- Lowest lamp cost

Disadvantages

- Lowest energy output
- Increased number of lamps required

  - typically limited to low flow rate applications
- Largest system size
  - increased number of channels required to accommodate lamp modules
- No lamp output modulation capability
- Reduced degree of process automation
- Periodic disconnection and removal of lamp modules or lamp banks for manual and/or chemical cleaning of quartz sleeves or replacement of lamps
- Requirement for cleaning stations and lifting devices to move banks of lamps
- Increased labour requirements for O&M
- Not suitable for low quality wastewaters

6.1.2 Low Pressure / High Intensity Systems

A range of different reactor designs from simple to complex is commercially available. Lamp outputs also vary considerably depending on the system. LP/HI systems incorporate the benefits of LP/LI and MP/HI systems.

Advantages

- Generally simple designs for most systems
  - can be installed into open channels
  - horizontal and vertical lamp arrangements are available
- Medium to high energy output
  - most systems utilize lamps with power consumption ratings of <500 W; however, certain systems are available with higher power rating
- Lamp output modulation capability
- Reduced number of lamps required
  - can generally be applied to all flow rate ranges
  - higher intensity lamp systems more suited to medium to high flow rates
- Reduced system size
  - smaller footprint than LP/LI systems
- Medium to high energy efficiency
  - monochromatic irradiation at optimum germicidal wavelength
  - higher energy efficiency than MP/HI lamps
- Automatic cleaning system
  - mechanical or mechanical/chemical cleaning

  - optional for some processes
- Automatic monitoring and control system
  - wide range of automation and control available, depending on the process
- Reduced labour requirements for O&M
  - applies especially to processes utilizing automatic cleaning and advanced process control systems
- Medium to long lamp life for most systems
- Most common technology available from the main manufacturers
  - wide range of lamp outputs
  - various reactor designs

Disadvantages

- Increased complexity of some system designs
  - may increase O&M requirements and associated costs
- Periodic disconnection and removal of lamp modules for chemical cleaning of quartz sleeves (i.e., for systems without provision for automatic cleaning) and/or replacement of lamps
  - modules are heavier than those of LP/LI systems and may be more difficult to handle
- Cleaning stations and lifting devices are required (i.e., for systems without provision for automatic cleaning)
- Moderate lamp life for highest output system
- Medium to high lamp cost
- Increased fouling potential for systems with elevated lamp temperatures
  - may necessitate automatic cleaning system

6.1.3 Medium Pressure / High Intensity Systems

MP/HI systems are available in either in-channel (i.e., horizontal lamps, parallel to flow, installed into open channels) or in-pipe (i.e., horizontal lamps, perpendicular to flow, closed chamber) configurations.

Advantages

- Highest lamp energy output
  - potentially suitable for low quality wastewaters
- Lamp output modulation capability
- Lowest number of lamps required

- Compact systems
    - smallest footprint
- Self contained reactors that can be easily installed into wastewater channels or pipes
- Automatic monitoring and control system
- Automatic cleaning system
    - mechanical or mechanical/chemical cleaning
- Reduced maintenance requirements
    - easy accessibility to lamps
    - lifting mechanism for easy removal of lamp module from channel to facilitate lamp maintenance and replacement
    - easy and quick removal and replacement of lamps with in-pipe system

Disadvantages

- Increased system complexity
- Lowest energy efficiency and highest electricity consumption and associated cost
- Shortest lamp life
- Medium to high lamp cost
- Relatively high headloss per bank of lamps
- Increased fouling potential due to elevated lamp temperatures
    - necessitates automatic cleaning system
- Minimum flow requirement
- Cool-down periods before re-starts (see **Section 3.3.7** for more details on lamp cool-down and warm-up periods)

6.2 Screening of UV Processes and Equipment

Each of the commercially available UV technologies is potentially applicable for the disinfection of municipal wastewaters under various possible scenarios, irrespective of wastewater quality (i.e., secondary or tertiary filtered effluent) or flow rate. Generally, the suitability (i.e., technical and economic feasibility) of the different lamp technologies and process configurations is dependent on site-specific characteristics.

For wastewaters with low UVT (e.g., primary treated effluents), the high intensities of medium pressure and certain low pressure lamps may be advantageous for disinfection.

This chapter provides a decision-making tool to assist with preliminary UV process selection for applications involving the disinfection of secondary treated effluents from activated sludge type processes or of tertiary filtered biological process effluent. In general, wastewater flow rate will be a major factor influencing the type of UV lamp technology for such applications. For the purposes of the screening procedure, municipal WWTP sizes are divided into the following categories according to average design flow rate:

- Small plants = Less than 5 MLD [1.3 US MGD]
- Medium-sized plants = 5 to 50 MLD [1.3 - 13 US MGD]
- Large plants = Greater than 50 MLD [13 US MGD]

As outlined in **Section 6.2.1**, in addition to WWTP size (i.e., corresponding to wastewater flow rate), a number of other key criteria are used as a basis for process technology screening. A decision-tree format is used for the screening of technologies and identification of suitable options (i.e., category of lamp technology) according to key criteria. Systems screening is based on available technical literature and cost information and experiences obtained from contacts with the technology vendors and users.

It must be emphasized that the process screening is for preliminary use and that the actual selection of an appropriate technology and design will be very site specific. The suggested category of lamp technology identified as being most appropriate based on process screening is not intended to be exclusive. The suggestions should not be construed as ruling out consideration of the other UV process alternatives.

A general list of possible factors for consideration in process selection and some elaboration and discussion is provided in **Section 6.3**. The weighting of these factors and considerations will be different depending on the particular application and site limitations and preferences. This will typically be assessed by the municipal engineer together with an engineering consultant and/or the technology manufacturers.

In summary, the screening tool provided in this report is intended to provide guidance to municipal engineers to facilitate decision-making in the initial stages of a wastewater disinfection project. The screening tool together with the list of various factors and considerations provides a useful basis for identifying and developing an appropriate site-specific UV disinfection solution.

6.2.1 Key Screening Criteria

The following are the key criteria used in the sample decision tree for UV process technology screening for various disinfection scenarios.

- WWTP size (which relates to wastewater flow rate)
    - small
    - medium
    - large
- Number of UV lamps (e.g., minimum number of lamps)
    - also relates to UV system size

- Lamp output modulation
    - permits dose pacing
- Energy efficiency
- Automatic cleaning system
    - mechanical or mechanical/chemical
- Acceptable headloss
- Number of reference sites (i.e., demonstrated successes in similar applications)

Listed below are other important criteria for consideration in process selection. However, these are not used in the decision tree for UV process technology screening since they require more detailed site-specific evaluation. A discussion of possible site-specific and process-specific factors and considerations is provided in **Section 6.3**, while a brief discussion on the development of short lists of appropriate process options for evaluation and selection is provided in **Section 6.5**.

- Wastewater quality
    - high industrial contribution; low UVT
    - high and/or variable TSS concentrations
    - scaling/fouling potential
    - wastewater by-pass scenarios
- Degree of process automation
- O&M labour requirement (see **Section 6.3.1** for more details)
- Capital cost
- Life-cycle cost (see **Section 6.3.1** for more details)
- Degree of complexity
- Retrofit application
    - dimensions of existing open channel system
    - dimensions of existing chlorine contact chamber
    - WWTP hydraulic profile

6.2.2 UV Processes Screening

The focus of the preliminary process screening is for disinfection applications involving secondary treated effluent from activated sludge processes. Typical UV transmission and TSS concentrations range between 50 to 75% and less than 10 to 30 mg/L, respectively. The decision tree applies equally to filtered activated sludge process effluent (i.e., tertiary treated effluent). The main impact of tertiary filtration will be reduced UV dose requirements and size of the suggested UV technology, in view of the enhanced effluent quality in terms of UVT, TSS concentration, particle size, and colloidal content. The decision tree may also apply to tertiary filtered effluents from non-activated sludge biological treatment processes, assuming that particulates (e.g., sloughed solids from attached growth processes) are effectively removed and that filtered UVT levels are similar to those of a typical secondary treated quality effluent.

All of the commercially available processes described in **Chapter 4** are potentially applicable for disinfection of activated sludge secondary or tertiary treated effluents. The decision tree indicates the most appropriate lamp technologies according to the key screening criteria. In the case of LP/HI systems, a further breakdown is arbitrarily set for lamp power ratings of less than 500 W (i.e., level 1) and higher wattage lamps rated at 500 W or greater (i.e., level 2). The main considerations between these two levels of lamp power will be the number of lamps required and the number of reference sites. For the LP/LI and LP/HI process technology categories, various system lamp configurations (e.g., horizontal or vertical placement of lamps, and parallel versus perpendicular flow arrangements) are possible. The selection of the most appropriate configuration will be site specific, taking into account such factors as the dimensions of open channels at existing WWTPs.

Figure 6.1 provides the sample decision tree for the suggested UV process technologies for various situations and screening criteria. It should be cautioned that the decision tree or selection tool follows an arbitrary approach and only identifies a format or process to use to try and make an initial screening of potential issues and the impact these may have on UV selection. The user can use this approach and their own criteria and potentially weighting to make a decision tree or selection tool for their own application. For two example applications of the decision tree, refer to **Section 6.4**.

UV disinfection of primary treated effluent is not an established application of UV technology, although successful full-scale examples exist. Owing to poor and variable associated effluent quality (i.e., typical UVT levels of 5 to 25%, TSS concentrations of 30 to 150 mg/L, and elevated fats, oils and grease), MP/HI systems may be the most suitable UV disinfection option. LP/HI lamps are also potentially applicable in the case of chemically assisted primary treated effluents, provided that the system is designed with the appropriate centerline spacing and fitted with a properly functioning cleaning system.

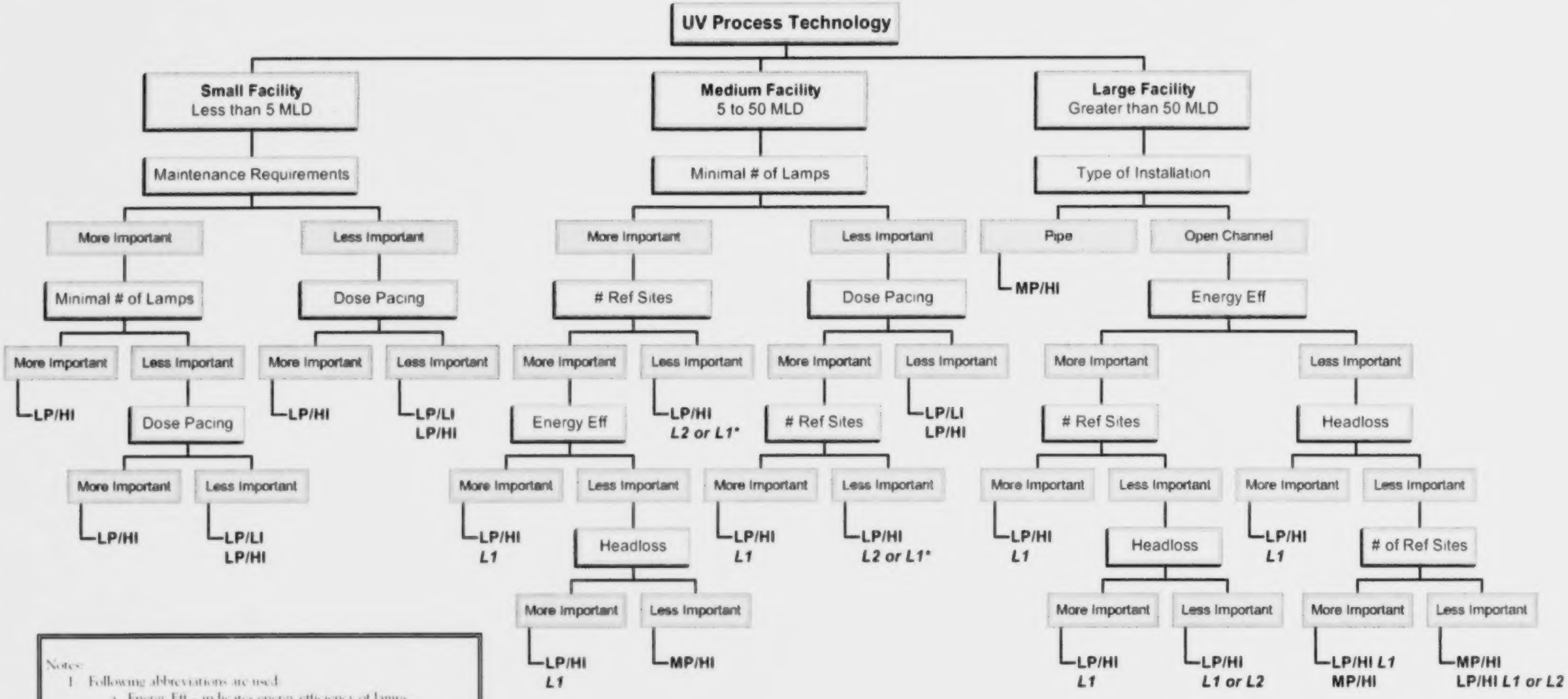
6.3 Factors for Consideration in UV Process Selection

Following the preliminary identification of suitable UV process technologies based on the key screening criteria, a number of factors and considerations will determine the most appropriate technologies and system design and configuration for a particular application. Possible site-specific and process-specific factors are outlined below. A number of these factors have been discussed in previous sections of this manual, and some are elaborated upon in **Section 6.3.1**.

As a minimum, the following **general factors** should be given consideration in process selection:

- Capability to satisfy effluent discharge criteria (e.g., with respect to microbiological indicator parameters and limits relevant to disinfection)
- Raw wastewater characteristics (e.g., industrial contribution with potential impacts on UVT)

Figure 6.1 Example Decision Tree for Preliminary Selection of UV Technologies for Various Applications


UV Process Technology
Small Facility
Less than 5 MLD
Medium Facility
5 to 50 MLD
Large Facility
Greater than 50 MLD
Maintenance Requirements
Minimal # of Lamps
Type of Installation
More Important
Less Important
More Important
Less Important
Pipe
Open Channel
MP/HI
Minimal # of Lamps
Dose Pacing
# Ref Sites
Dose Pacing
Energy Eff
More Important
Less Important
More Important
Less Important
More Important
Less Important
More Important
Less Important
More Important
Less Important
LP/HI
LP/HI
LP/LI
LP/HI
LP/HI
L2 or L1*
LP/LI
LP/HI
Dose Pacing
Energy Eff
# Ref Sites
# Ref Sites
Headloss
More Important
Less Important
More Important
Less Important
More Important
Less Important
More Important
Less Important
More Important
Less Important
LP/HI
LP/LI
LP/HI
LP/HI
L1
LP/HI
L1
LP/HI
L2 or L1*
LP/HI
L1
LP/HI
L1
Headloss
Headloss
# of Ref Sites
More Important
Less Important
More Important
Less Important
More Important
Less Important
LP/HI
L1
MP/HI
LP/HI
L1
LP/HI
L1 or L2
LP/HI L1
MP/HI
MP/HI
LP/HI L1 or L2

Notes:
1. Following abbreviations are used:
    a. Energy Eff – indicates energy efficiency of lamps
    b. # Ref Sites – indicates number of reference sites of lamp technology
    c. Headloss – headloss requirements
    d. Dose pacing – modulating the power to the lamps
2. Lamp abbreviations are:
    a. LP/LI – low pressure/low intensity
    b. LP/HI – low pressure/high intensity
    c. MP/HI – medium pressure/high intensity
3. L1 and L2 indicate wattage of lamps, L1 (Level 1) is less than 500 W per lamp, L2 (Level 2) is greater than 500 W per lamp
4. Lamp orientation options are available for a number of units and should be assesed seperately
5. * indicates that headloss may need to be assesed for the LP/HI L2 lamps as well

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Consulting Engineers

Stantec

Project No. 332-04 E / March 13, 2003

Figure 6.1 - Example Decision Tree for Preliminary Selection of UV Technologies for Various Applications

- Disinfection process influent characteristics (i.e., level of upstream treatment and degree of effluent variability)
- Compatibility of the candidate UV technology with upstream processes and incorporation into the overall treatment plant flowsheet (e.g., hydraulic characteristics) of an existing municipal WWTP
- Site constraints (e.g., availability of space, utilities, skilled labour, etc.)
- Degree of process automation desired
- Degree of process redundancy desired
- O&M requirements of process
- Energy requirements of process
- Space requirements of process
- Occupational health and safety aspects
- Costs (e.g., capital and life-cycle cost of the UV system)

The following are more **specific factors** with potential influence on disinfection process selection and design:

- Type of treatment processes utilized at the municipal WWTP (i.e., primary treatment alone or secondary treatment using suspended growth, attached growth, or combined processes, etc.)
- Type of suspended growth secondary treatment process utilized (e.g., sequencing batch reactor process may require effluent discharge flow equalization)
- WWTP flow by-pass scenarios (i.e., secondary by-pass or plant by-pass) and corresponding flow rate thresholds and disinfection requirements
- Retrofit applications may include the following specific factors, considerations, and goals:
    - depth and dimensions of existing open channels
        - ideally, the retrofit/replacement system equipment will be able to fit into the existing open channel UV layout and buildings with minimal structural, mechanical, and electrical modifications
    - dimensions of existing contact chamber(s)
    - hydraulic constraints at the site
        - ideally, the headloss at peak flow conditions will be equal to or less than through the existing system
    - goals in retrofitting an existing disinfection system with a new UV process may include:
        - significantly reduced number of lamps required to achieve consistent disinfection

- increased energy efficiency
- reliable, efficient, low maintenance, and operator friendly performance characteristics
- increased degree of process automation
- no increase in lamp scaling or cleaning difficulties than are experienced with the existing system
- minimal capital and life-cycle cost

The following are **process-specific** characteristics that will require consideration:

- Required number of UV lamps
- Process complexity
- Standard and optional features
- Power supply and distribution system characteristics
- Type of automatic cleaning system, if any
- Degree of on-line process monitoring and control
- Automatic process control strategy (i.e., flow pacing, dose pacing, etc.)
- Degree of process flexibility (e.g., for optimization and/or future expansion)
- Degree of redundancy
- Configuration, geometry, and dimensions of the disinfection system (i.e., especially important for retrofit applications)
- Reactor hydraulic characteristics
- Capital and life-cycle costs
- Number of similar full scale installations (i.e., reference sites), years of successful full-scale experience, and relevant operational information with a particular technology
- Guarantees and warranties on equipment components, replacement prices, and system performance
- Location of vendor and availability of technical support and service

The importance and relative weighting assigned to the applicable factors will be project specific and will influence the comparative evaluation of process alternatives for a particular application. Elaboration on some of the considerations for application of UV technology is given in **Section 6.3.1**, while the benefits of UV reactor validation and pilot plant testing to address uncertainties and considerations for certain applications are discussed in **Sections 6.3.2 and 6.3.3**, respectively. **Chapter 7** summarizes preliminary capital and O&M cost information, on the basis of defined generic conditions, that was received from various manufacturers of the alternative technologies.

6.3.1 Miscellaneous Considerations and Details

Various technical and non-technical factors for consideration in process selection are outlined and elaborated upon below.

- Life-cycle cost assessments take into account the initial capital cost of the UV system (i.e., including process equipment and related components and any necessary structural modifications) and O&M costs (i.e., for power, system maintenance, cleaning chemicals, and parts replacement, especially lamps and ballasts)
    - important considerations in evaluation of new facility and upgrade applications (i.e., trade-off between higher capital costs of high UV output systems and potential O&M cost savings)
    - continuous versus seasonal disinfection will impact on the life-cycle cost assessment and estimated pay-back periods
- O&M labour requirements will vary depending on the UV process and can include:
    - routine system monitoring
    - preventive maintenance and repair
    - extensive maintenance activities (e.g., removal of lamp modules for cleaning and lamp replacement)
- TSS concentration and particle size can influence UV disinfection process selection and design
- UV disinfection of municipal wastewaters other than activated sludge-based secondary treatment process effluents or tertiary filtered secondary process effluents are not covered in this manual and will require special consideration:
    - primary treated effluents contain increased levels of TSS, dissolved and colloidal organics and colour, with increased variability, that require an increased level of UV dose and intensity of irradiation
    - lagoon process effluents have potentially higher effluent TSS concentrations than activated sludge processes, albeit smaller average particle sizes; facultative lagoon effluents experience seasonal variations in effluent TSS content (e.g., algal biomass) which may require filtration prior to the UV disinfection stage; microscopic algae present in facultative lagoons can decrease effluent UVT
    - secondary treated effluents generated by attached growth biological processes (e.g., trickling filters, rotating biological contactors, biological aerated filters) are more difficult to disinfect owing to reduced effluent UVT levels and/or larger particle sizes compared to activated sludge process effluents; higher UV doses may be required to meet target disinfection levels due to the larger particle sizes, despite low TSS and satisfactory UVT levels (Newbigging *et al.*, 1997); depending on disinfection requirements, tertiary filtration may be required
    - hybrid processes such as the trickling filter/solids contact (TF/SC) and integrated fixed film activated sludge (IFAS) processes will have similar quality effluents and

disinfection requirements as conventional suspended growth activated sludge systems due to the flocculation of biomass as part of the mixed liquor and improved control of effluent TSS and particle size

- Tertiary filtration (e.g., with conventional sand filters or dual media filters) will reduce differences in the treatability by UV irradiation of effluents generated by various types of secondary treatment processes (e.g., activated sludge, attached growth systems such as trickling filters and rotating biological contactors, hybrid systems such as trickling filter/solids contact, lagoons)
    - tertiary treated effluent will generally require a lower UV dose for a given treatment target than for the corresponding secondary treated effluent
    - tertiary filtered effluents will contain a lower TSS concentration and average particle size and distribution
    - impacts of tertiary treatment can be evaluated by unfiltered and filtered UVT measurements with representative samples of the secondary treatment process effluent
    - pilot plant testing may be worthwhile in the case of less established applications such as the UV disinfection of tertiary filtered effluents from lagoon or attached growth processes, to determine dose requirements
- Effluent reuse applications would require effective secondary treatment and tertiary filtration to enhance the effectiveness of the downstream UV disinfection stage
    - maximizes the quality and consistency of effluent to the disinfection process
- Secondary treated effluent exposed to sunlight upstream of the disinfection process stage can result in difficulties with strands of algae that can potentially build up at the front of the UV system and interfere with performance
    - this algal matter and other oversized material could be effectively removed through tertiary filtration
- Variability of effluent flow rate associated with certain secondary treatment processes can impact on UV system selection and design
    - intermittent and variable (i.e., periodically high) flows from SBRs must be taken into account in UV process selection and design and may require flow equalization
    - potential difficulties with effluent heating during low flow or stagnant periods in the case of high intensity lamp applications
- Pilot plant demonstration studies can provide useful side-by-side comparative performance assessments of alternative processes, which may facilitate the selection of the most appropriate UV process for a given application. Additional discussion and considerations are provided in **Section 6.3.3**.
    - pilot plant testing of UV disinfection is especially recommended for cases where the contribution of industrial discharges to the sewer is high or for the less established

  applications involving primary effluent or attached growth or lagoon-based secondary treated effluent disinfection
  - pilot scale testing of the upstream biological process(es) will also be required for prospective "greenfield" applications to generate representative effluent samples for characterization and UV disinfection testing
- Some UV processes require ancillary equipment and components, for example:
  - power transformers for externally mounted ballasts
  - HVAC systems for ballasts installed in cabinets
  - ballast cooling system comprising a heat exchanger with a circulating coolant such as propylene glycol for certain processes
- Increased potential rate of quartz sleeve scaling with MP/HI systems due to hotter lamp temperatures
  - automatic cleaning system required for MP/HI systems
- Instrumentation is available for on-line monitoring of important UV disinfection system parameters, some of which can be used as a basis for automatic control depending on the process, including:
  - flow rate
  - UV lamp intensity
  - UVT
  - Turbidity/TSS
- System automation can include the control of:
  - Lamps (i.e., on/off operation and/or modulation of power output for flow or dose pacing)
  - cleaning system operation
  - monitoring of on-line sensors
  - signaling of alarm conditions
  - safety shutdowns using interlocks
- Sophisticated controls are available for some UV technologies permitting the modulation of lamp power output based on influent flow rate and quality
  - automatic control of the UV disinfection system is often based on on-line flow rate and UVT measurements
  - UV intensity measurements are used as a control basis for some systems
- Automatic mechanical and chemical cleaning systems for the UV quartz sleeves reduce maintenance requirements for cleaning to a manageable level for large facilities

  - automatic cleaning systems are essential for MP/HI disinfection systems to control the rate of scale buildup at the higher lamp operating temperatures

- If a minimum number of lamps and energy efficient designs are important considerations but automatic cleaning is not considered essential, certain manufacturers will offer LP/HI technology without an automatic cleaning system
- Uniformity in the type of UV disinfection processes installed at other WWTPs in the particular municipality that includes a candidate site could be beneficial and may be a consideration
  - inventory of required spare parts that can be available for all of the facilities
  - sharing of process-specific operational experiences and practices

6.3.2 Validation of UV Reactor Performance

The UV fluence rate (i.e., UV intensity) cannot be measured directly in a complex, multiple lamp reactor, therefore, UV disinfection effectiveness for different reactor designs is difficult to measure and compare. UV fluence (i.e., dose) can be calculated mathematically, however, this has led to exaggerated claims due to incomplete characterization of a reactor's distribution of hydraulic residence times (i.e., due to the degree of mixing in the reactor) and the UV output of lamps.

The use of UV intensity sensor readings to estimate UV dose has a number of associated uncertainties, including possible loss of sensor sensitivity and non-optimal hydrodynamics. UV intensity sensors provide an indication of intensity at a single location and, therefore, cannot determine average UV intensity and dose in a three-dimensional reactor (WERF, 1995).

Although no method exists to provide precise results of actual UV dose, relatively accurate doses can be assigned through the use of bioassays. UV bioassays, also referred to as biodosimetry, represent an established scientific approach that makes use of known responses (i.e., the percentage survival of a specific indicator microorganism to a known UV dose) to determine the UV dose delivered by a specific reactor configuration. The surrogate indicator organism is spiked into the reactor influent and the degree of inactivation is measured based on the surviving number in the process effluent. A delivered UV dose corresponding to the level of inactivation achieved can then be assigned.

UV system validation testing consists of quantifying the inactivation of a virus surrogate (e.g., MS-2 bacteriophage) as a function of flow rate through the disinfection system (Metcalf & Eddy, 2003). The flow rate is normalized to the number of lamps within the system being tested, so that full-scale disinfection system design can be based on the hydraulic loading rate (e.g., L/min per lamp). In addition to control and measurement of the flow rate, UV transmission, suspended solids and UV lamp power during the test are also characterized.

UV reactor validation involves two steps, namely (i) comparison of UV system components with documentation from the manufacturer and (ii) measurement of dose delivery using biodosimetry. Validation provides accurate data on UV dose delivery capability over a defined range of influent flow rates, lamp power, and UVT. This approach can confirm the UV output of lamps under actual operating conditions. The prediction and verification of UV reactor performance is useful for determining the capability of a reactor in achieving dose targets. This also permits performance comparisons between processes, if standardized test protocols are used.

Other aspects and benefits associated with UV bioassays are outlined below.

- UV reactor validation is performed by standardized bioassays using a specific UV-resistant surrogate microorganism
  - the surrogate organism should be easy to work with, have a log-linear response to UV, and respond consistently within the UV dose range of interest
  - it is desirable for the UV resistance of the selected surrogate organism to be similar to that of the target microorganism(s) used to assess regulatory compliance
  - MS-2 phage and *B. subtilis* spores, being much less sensitive to UV than coliform bacteria, are two microbes typically used for bioassays as they can reliably provide a log linear response in the dose ranges of interest (e.g., 20-40 mJ/cm^2 for typical wastewater disinfection requirements)
- The bioassay needs to be conducted on the equipment and system configuration that are fully representative of the application.
  - this includes lamp spacing, lamp and ballast output, wiper assemblies, etc.
- Testing of the hydraulic performance of the UV disinfection system is performed to verify the uniformity of the approach and exit velocities
- For LP/LI UV systems, a minimum of two banks must be tested but typically more are used (Metcalf & Eddy, 2003)
- The carefully controlled bioassay experiments involve the enumeration of microorganisms in the reactor influent and effluent and, by use of a calibration curve (i.e., based on collimated beam testing results), a curve showing **flow rate per lamp** versus **actual UV dose delivered** is developed
  - this curve reveals the influent flow rate that can be applied per lamp to achieve a given fluence level (i.e., UV dose)
  - reactor limitations would be reflected by a reduced flow rate per lamp value to meet the disinfection requirements; this would also correspond to a higher power consumption per volume of water treated
- Bioassay results together with tracer studies to determine average retention time can be used to calculate the average UV intensity over the range of flow rates tested
- Potentially represents an unbiased assessment and certification of UV system performance, if well-defined and standardized bioassay protocols are used.
  - allows for more accurate and direct comparisons of the capabilities of different UV systems

  - provides direct indication of reactor disinfection performance
- The measurement of dose delivery using biodosimetry can be compared with the dose delivery indicated by the reactor's on-line monitoring system
- Offers a practical means of understanding inactivation dynamics of UV reactors

6.3.3 Pilot Plant Testing and Demonstration

Information obtained from pilot plant testing and demonstration studies, particularly side-by-side performance testing of alternative processes, can be useful in the selection of the most appropriate UV process for a given application. Pilot plant testing may be especially useful for less established applications of UV technology for which there is limited full scale experience or where uncertainty exists concerning the feasibility of UV disinfection or the applicability and design of a particular process. The requirement for pilot plant testing is case-specific. Some manufacturers recommend pilot plant evaluations for certain applications (e.g., UV disinfection of primary treated effluent) while others do not.

Cases where pilot plant investigations could be beneficial include:
- Large contribution of industrial wastewater to the municipal WWTP influent and where the potential impact on wastewater UVT can be significant
- Influent wastewater from primary treatment
- Influent wastewater from attached growth secondary treatment
- Influent wastewater from lagoon-based treatment
- Elevated levels of iron in the influent wastewater (i.e., 0.3 mg/L or more)
- Influent wastewater constituents and concentrations (e.g., hardness levels of 300 mg/L or more) that have the potential to cause pronounced difficulties with lamp sleeve fouling

Pilot plant studies involving the evaluation of one or more processes are useful for determining, verifying, and demonstrating:
- Applicability of UV disinfection
- UV disinfection process performance capabilities, including:
  - treatment effectiveness
  - process reliability, operability, and flexibility; applies to UV lamps, ballasts, automatic cleaning system, sensors and monitors, control system, etc.
- Verification and confirmation of vendor claims, including UV dosing capabilities
- Hydraulic characteristics, limitations, and requirements
- O&M characteristics, limitations, and requirements, including:
  - power consumption
  - cleaning requirements

  - chemical consumption
  - equipment maintenance
- Design parameters
- Safety factors
- Process economics
- Sensitivity analysis for critical process parameters
- Relationships between effluent quality parameters

Pilot scale demonstrations offer the valuable opportunity for direct comparative assessments of alternative UV process technologies and system designs and configurations in terms of disinfection capabilities and operational performance. In particular, pilot plant demonstrations are warranted for the evaluation of innovative UV process technologies for which there is limited, if any, full scale experience.

The pilot plant components and design must be representative of the respective full-scale system and should be large enough to provide meaningful data to facilitate the scaling up of results. For example, the ratio of influent flow rate per UV lamp and hydraulics should be similar to the full-scale unit. Various flow rates should be tested (e.g., below, equal to, and above the design flow rate per UV lamp). The actual delivered UV dose at all flow rates can be used as a basis to verify the validity of performance claims. This dose can be determined with UV bioassays.

Pilot plant studies can be used to simulate various possible scenarios of influent wastewater characteristics (e.g., flow rate, quality, and variability) representative of the proposed full-scale application (i.e., present and future). It is important that the stream(s) tested are representative. In the case of "greenfield" applications, the candidate biological process(es) and tertiary filtration process will also have to be pilot tested to generate representative effluent for characterization and UV disinfection testing. This can also facilitate the testing of various possible scenarios and operational conditions.

Information generated during pilot plant studies can be used as a basis for full-scale process selection and design, including suitable safety factors for lamp aging and sleeve fouling. Design considerations include UV dosing capacity and capabilities, pretreatment, cleaning systems, and on-line control requirements. Cost estimates (i.e., capital and life-cycle costs) associated with the applicable process types can be generated.

Long-term pilot plant testing over a period of a number of months can be used to:

- Investigate the potential for difficulties with lamp sleeve scaling and fouling
- Develop suitable remedial operating strategies (e.g., cleaning procedures and frequencies; suitable cleaning chemicals)
- Assess the effectiveness and integrity of automatic cleaning system mechanisms for the wiping of lamp sleeves and UV intensity sensors

  - an unwiped lamp sleeve could serve as a control to assess the potential rate of scaling/fouling and for comparison with the wiped sleeves
  - remove lamp sleeves after long term operation and test the degree to which manual cleaning can restore the original transmittance
- Evaluate lamp life and effectiveness over time
  - tests for lamp aging (i.e., due to solarization of the lamp glass) are quite involved
- Evaluate the reliability of sensors, monitors, and automated control systems
- Assess the impacts of potential seasonal variations in raw sewage and secondary treated wastewater composition on UV process performance, and develop suitable operational strategies and procedures
  - generate relevant operating experience

Relationships can be established between disinfected effluent quality and corresponding UV dose levels and influent characteristics (e.g., UVT and suspended solids) for various scenarios.

While the experimental plans and testing requirements can be defined by the owner and/or consultant, the actual operation of the pilot plant equipment may have to be conducted by the manufacturer due to the need for process-specific knowledge.

6.3.3.1 Pilot Plant Program Activities

An itemized summary of important pilot plant program activities is listed below.

1. Problem identification
2. Definition of pilot plant testing and demonstration goals
3. Selection of engineering consultant to co-ordinate the pilot plant trials
4. Identification and selection of alternative treatment processes to be tested
5. Design and fabrication of pilot plant(s) and/or rental of units from process manufacturers
6. Arrangements for equipment, instrumentation, materials and supplies
7. Hook-up of utilities and influent supply
8. Development of clear experimental plans, including sampling schedules and monitoring parameters
9. Development of O&M strategies, plans and schedules
10. Start-up, operation, and monitoring of pilot plant(s)
11. Effluent sampling and analysis
12. Collection, compilation, and analysis of experimental data
13. Performance assessments

14. Reporting of results and recommendations
15. Overall project management

The consultant engineer assigned to manage the project would need to have relevant experience and a process engineering background including a comprehensive understanding of UV treatment process fundamentals. A research & development background would be beneficial and a possible criterion for selection of the consultant.

6.4 Examples of Technology Screening

The following two examples are provided to illustrate the application of the preliminary decision tree presented in **Figure 6.1**. The first example is for a new installation, and the second example is a retrofit application.

6.4.1 New Facility Installation

The City of Windsor Lou Romano Water Reclamation Plant (LRWRP) will be used as an example of a WWTP at which a new UV disinfection process might be installed as part of an overall plant upgrade from chemically assisted primary treatment to secondary treatment with effluent disinfection. The LRWRP is a large facility with a rated average day capacity of 159 MLD that currently uses alum and a polymer for enhanced primary treatment. Extensive pilot testing of potential secondary treatment processes for the upgrade of this facility have been conducted (Hydromantis and Stantec, 2001). The results of this work indicate that one of two hybrid fixed film systems will be utilized for the upgrade of the facility. These processes are the trickling filter/solids contact process (TF/SC) or the biological aerated filter (BAF) process. These processes were proven to provide at least the equivalent of secondary treatment, in a more cost-effective manner than conventional activated sludge. Since both recommended processes are non-traditional, UV pilot testing was conducted (Newbigging *et al.*, 1997). **Table 6-1** provides a summary of the process effluent or UV influent expected from each process.

Table 6-1 Process Effluent Characteristics from Pilot Processes Recommended for LRWRP Upgrade

Parameter	TF/SC	BAF
Flow (L/min)	181	21
Effluent Concentrations (mg/L)		
Suspended Solids	9	5
Carbonaceous BOD_5	6	6
Total Phosphorous	0.4	0.5
Total Ammonia-N	1.6	1.5
E. coli (CFU/100 mL)	25,000	16,000

Note: Effluent concentrations based on period from July 1994 to August 1995, bacterial values from July to August 1995.

The results indicate that both processes provide the equivalent of secondary treatment in terms of conventional effluent parameters. UVT tests were also conducted indicating both process had high transmittance, averaging 75 and 72% for the TF/SC and BAF, respectively.

Using the example decision tree, the potentially most suited UV technology for this plant can be determined, based on the expected preferences for this site. **Figure 6.2** shows the potentially appropriate UV technology for this site and conditions. Decisions include:

1) Step 1 - Large facility, averaged design capacity of 159 MLD.
2) Step 2 - Expected type of installation, open channel. This decision is based on the current layout of the plant that mainly utilizes open channels and the design at the City's other wastewater facility.
3) Step 3 - Energy efficiency, energy usage is a large component of the overall O&M costs for the City. This decision may be difficult to make at this time given the uncertainty of energy costs in Ontario. For this evaluation a review of both scenarios is made:

a) Step 3a - Energy efficiency is important, Step 4a number of reference sites for equipment. Without extensive piloting, the City would be more likely to consider systems with a proven track record and numerous sites for inspection and review. Therefore, based on this scenario, a low pressure/high intensity level 1 (LP/HI L1) system would be recommended.

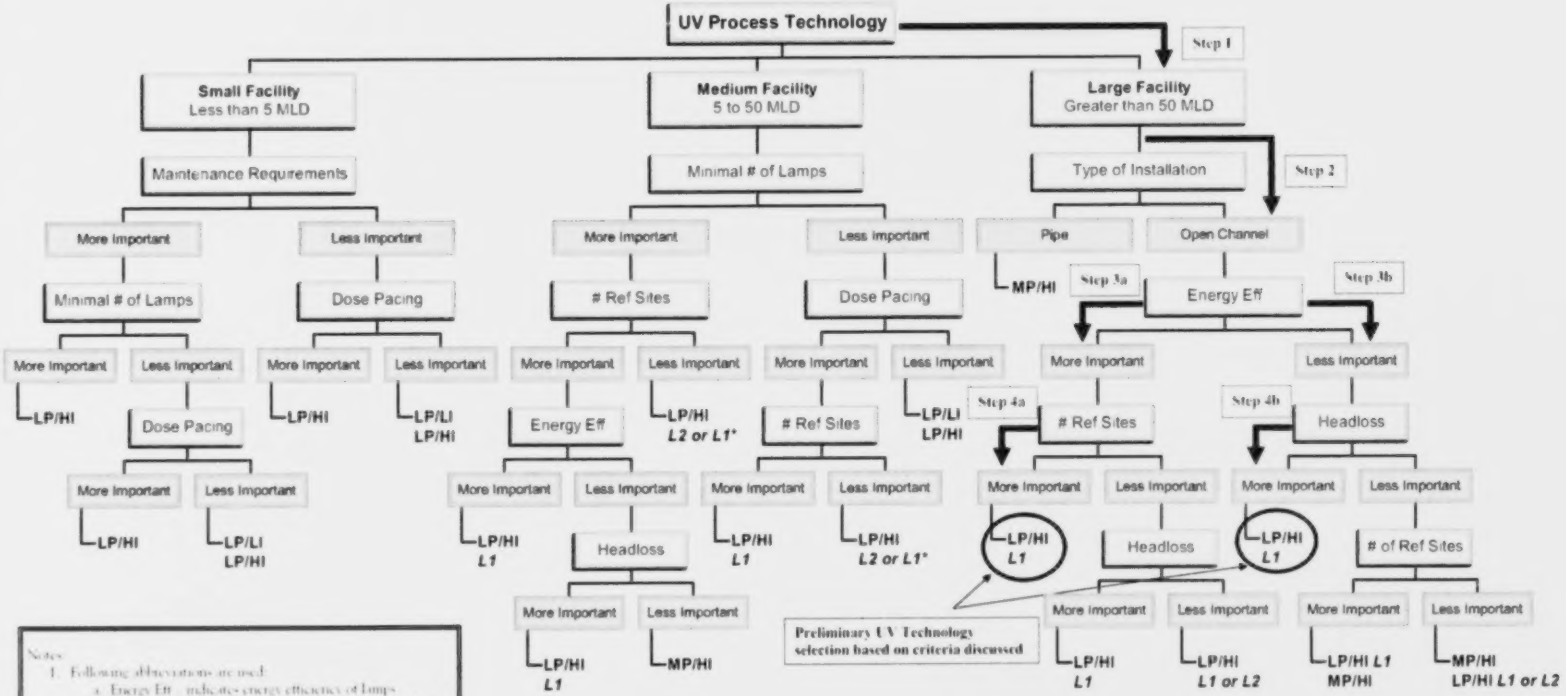
b) Step 3b - Energy efficiency is not as important, perhaps based on a complete O&M cost evaluation. Step 4b headloss concerns. Although the proposed secondary process designs will include a primary effluent pumping station, soil conditions at the LRWRP are such that reactors and tanks are elevated. Based on the soil conditions minimizing the channel or reactor depth at the plant is expected to be important. Therefore, based on this scenario, a low pressure/high intensity level 1 (LP/HI L1) system would also be recommended.

The preliminary decision for the LRWRP is based on the criteria above. Other scenarios and UV technology recommendations could be made based on the importance of the various factors. One factor not considered during this evaluation was the observed high UV dosage required for the BAF process during the UV evaluation (Newbigging *et al.*, 1997). Both BAF effluent pilot operations and collimated beam tests indicated a higher than expected dosage for this process, despite the process' excellent (near tertiary quality) final effluent and good UVT results. Based on this issue a higher output UV system such as the LP/HI level 2 or the MP/HI process may be recommended and might become more important than direct energy efficiency and headloss concerns at the plant.

6.4.2 Retrofit Application

The City of Windsor Little River Pollution Control Plant (LRPCP) will be used as an example of a WWTP at which an existing conventional UV disinfection facility requires upgrading, retrofitting, or replacement. The existing UV system is a first generation LP/LI process. The LRPCP is an activated sludge plant with a high quality effluent using alum for phosphorous removal. LRPCP was an early

Figure 6.2 Example 1 Use of Decision Tree for Preliminary Selection of UV Technologies for LRWRP


UV Process Technology
Step 1
Small Facility
Less than 5 MLD
Medium Facility
5 to 50 MLD
Large Facility
Greater than 50 MLD
Maintenance Requirements
More Important
Less Important
Minimal # of Lamps
Dose Pacing
More Important
Less Important
LP/HI
Dose Pacing
More Important
Less Important
LP/HI
LP/LI
LP/HI
More Important
Less Important
LP/HI
LP/LI
LP/HI
Minimal # of Lamps
More Important
Less Important
# Ref Sites
Dose Pacing
More Important
Less Important
Energy Eff
LP/HI
L2 or L1*
More Important
Less Important
LP/HI
L1
Headloss
More Important
Less Important
LP/HI
L1
MP/HI
More Important
Less Important
# Ref Sites
LP/LI
LP/HI
More Important
Less Important
LP/HI
L1
LP/HI
L2 or L1*
Type of Installation
Step 2
Pipe
Open Channel
MP/HI
Step 3a
Energy Eff
Step 3b
More Important
Less Important
Step 4a
# Ref Sites
Step 4b
Headloss
More Important
Less Important
LP/HI
L1
Headloss
More Important
Less Important
LP/HI
L1
LP/HI
L1 or L2
More Important
Less Important
LP/HI
L1
# of Ref Sites
More Important
Less Important
LP/HI L1
MP/HI
MP/HI
LP/HI L1 or L2
Preliminary UV Technology selection based on criteria discussed

Notes:

1. Following abbreviations are used:
   - a. Energy Eff – indicates energy efficiency of lamps
   - b. # Ref Sites – indicates number of reference sites of lamp technology
   - c. Headloss – headloss requirements
   - d. Dose pacing – modulating the power to the lamps
2. Lamp abbreviations are:
   - a. LP/LI – low pressure/low intensity
   - b. LP/HI – low pressure/high intensity
   - c. MP/HI – medium pressure/high intensity
3. L1 and L2 indicate wattage of lamps. L1 (Level 1) is less than 500 W per lamp; L2 (Level 2) is greater than 500 W per lamp
4. Lamp orientation options are available for a number of units and should be assessed separately
5. * indicates that headloss may need to be assessed for the LP/HI L2 lamps as well

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Figure 6.2 - Example 1 Use of Decision Tree for Preliminary Selection of UV Technologies for LRWRP

user of UV technology for effluent disinfection with the installation of two systems in 1988, one for each plant. The system in Plant No. 1 is rated for an average daily flow of 36.4 MLD, while the system in Plant No. 2 is rated for 27.3 MLD. The UV systems are both low pressure/low intensity UV lamps. Each plant has two channels with two UV banks in each channel. Each bank contains a series of modules with 8 lamps in each module. Plant No. 1 has 704 lamps while Plant No. 2 has 512 lamps. The breakdown is as follows:

- Plant No. 1 – 22 modules per bank, 8 lamps per module, total of 176 lamps per bank with 4 banks (2 per channel) or 704 lamps in total
- Plant No. 2 – 16 modules per bank, 8 lamps per module, total of 128 lamps per bank with 4 banks (2 per channel) or 512 lamps in total

The layout of the two systems is identical. A bulkhead in Plant No. 2 can be removed and an additional 6 modules added to obtain the same configuration as in Plant No. 1.

Using the example decision tree, the potentially best UV technology for this plant can be determined, based on expected preferences for the site.

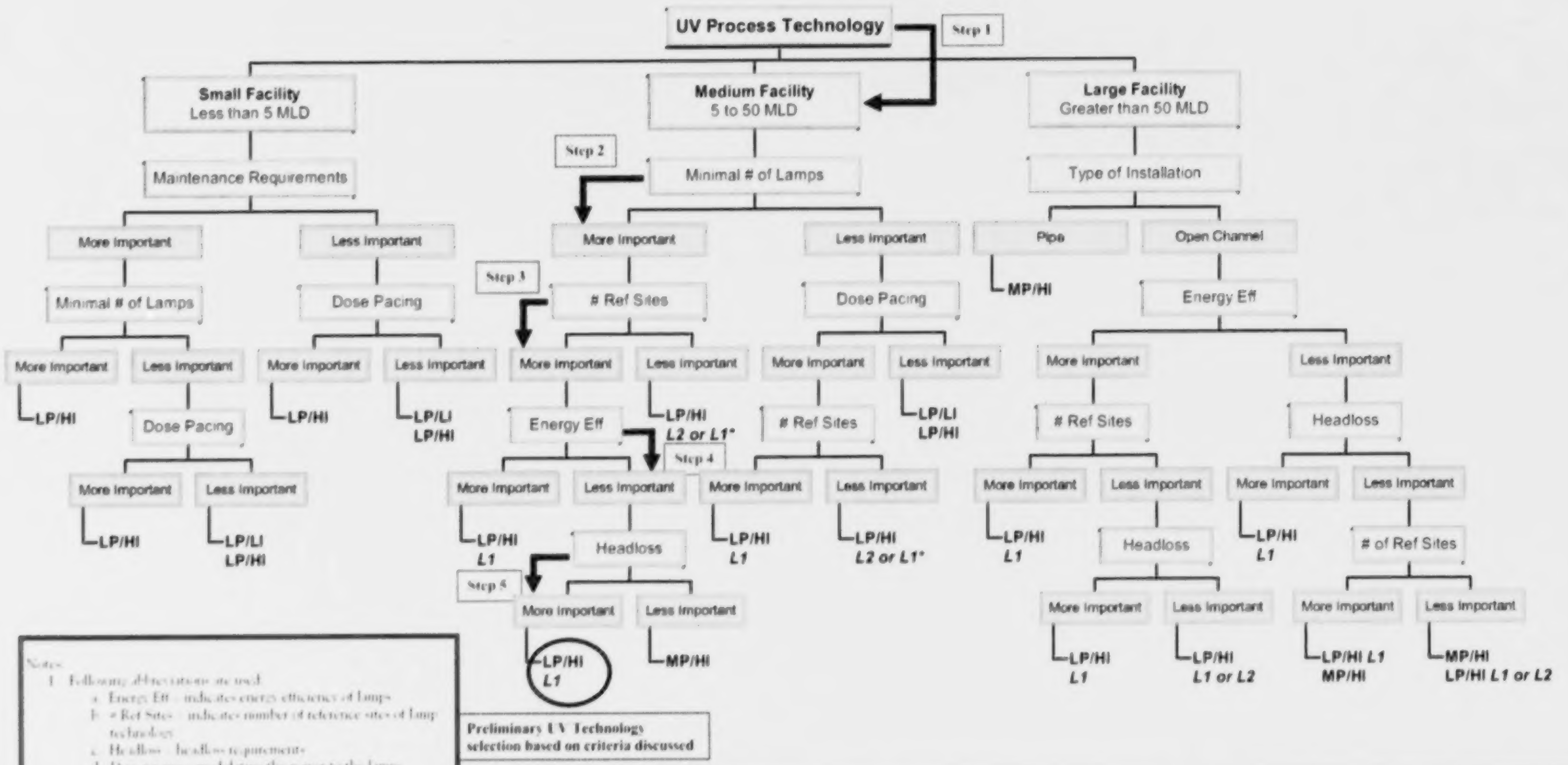
Figure 6.3 shows the potentially appropriate UV technology for this site and conditions. Decisions include:

1) Step 1 - Medium sized facility: Average design capacity of 36.4 MLD per plant.
2) Step 2 - Number of lamps: The City's existing system is a LP/LI and the number of lamps has been raised as an issue and is therefore expected to be important.
3) Step 3 - Number of reference sites for equipment: Without extensive piloting, the City would be more likely to consider systems with a proven track record and numerous sites for inspection and review.
4) Step 4 - Energy efficiency: Energy usage is a large component of the overall O&M costs for the City. However, for a medium sized plant, the energy costs have historically been only about one quarter of the overall O&M costs for the plant. Therefore, energy efficiency alone may not be as important at this plant.
5) Step 5 - Headloss concerns: The hydraulics at the plant are tight. Based on a review of the feasibility of a retrofit at the LRPCP (Stantec and Hydromantis, 2002) it is recommended that the headloss required through any new UV installation should be equal to or less than the headloss through the current system. Therefore, headloss through the system is important. As a result, based on this scenario, a low pressure/high intensity level 1 (LP/HI L1) system would also be recommended.

6.5 Developing a Short-List of Alternatives for Site-Specific Applications

The process screening tool or decision tree can provide a preliminary indication of potentially applicable UV technologies for various wastewater disinfection scenarios. Subsequent to the initial identification of applicable options, a short-list of process alternatives and system designs will need to

Figure 6.3 Example 2 Use of Decision Tree for Preliminary Selection of UV Technology for LRPCP Retrofit


UV Process Technology
Step 1
Small Facility
Less than 5 MLD
Medium Facility
5 to 50 MLD
Large Facility
Greater than 50 MLD
Maintenance Requirements
More Important
Less Important
Minimal # of Lamps
Dose Pacing
More Important
Less Important
LP/HI
Dose Pacing
More Important
Less Important
LP/HI
LP/LI
LP/HI
More Important
Less Important
LP/HI
LP/LI
LP/HI
Step 2
Minimal # of Lamps
More Important
Less Important
Step 3
# Ref Sites
More Important
Less Important
Energy Eff
LP/HI
L2 or L1*
Step 4
More Important
Less Important
LP/HI
L1
Headloss
Step 5
More Important
Less Important
LP/HI
L1
MP/HI
Dose Pacing
More Important
Less Important
# Ref Sites
LP/LI
LP/HI
More Important
Less Important
LP/HI
L1
LP/HI
L2 or L1*
Type of Installation
Pipe
Open Channel
MP/HI
Energy Eff
More Important
Less Important
# Ref Sites
Headloss
More Important
Less Important
LP/HI
L1
Headloss
More Important
Less Important
LP/HI
L1
LP/HI
L1 or L2
More Important
Less Important
LP/HI
L1
# of Ref Sites
More Important
Less Important
LP/HI L1
MP/HI
MP/HI
LP/HI L1 or L2
Preliminary UV Technology
selection based on criteria discussed

Notes:
1. Following abbreviations are used:
    a. Energy Eff – indicates energy efficiency of lamps
    b. # Ref Sites – indicates number of reference sites of lamp technology
    c. Headloss – headloss requirements
    d. Dose pacing – modulating the power to the lamps
2. Lamp abbreviations are:
    a. LP/LI – low pressure/low intensity
    b. LP/HI – low pressure/high intensity
    c. MP/HI – medium pressure/high intensity
3. L1 and L2 indicate wattage of lamps. L1 (Level 1) is less than 500 W per lamp, L2 (Level 2) is greater than 500 W per lamp
4. Lamp orientation options are available for a number of units and should be assessed separately
5. * indicates that headloss may need to be assessed for the LP/HI L2 lamps as well

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Figure 6.3 - Example 2 Use of Decision Tree for Preliminary Selection of UV Technologies for LRPCP Retrofit

be evaluated and developed on a case-by-case basis to meet a municipal WWTP's effluent objectives. This will be strongly dependent on site-specific characteristics. Some of the possible site-specific and process-specific factors for consideration are outlined in **Section 6.3**.

Through an initial assessment and prioritization of the site-specific and process-specific factors, various technical alternatives can be identified and evaluated. An external engineering consulting firm can assist the municipal engineer in defining the project-specific requirements and solutions, starting with a long list and leading to a subsequent short list of alternatives for evaluation, taking into account the various factors of importance. Proper conceptual design of alternative processes is essential. Together with information obtained from technology vendors and users, the most appropriate process can be selected for detailed design, installation, and implementation.

The general procedure for developing a short list of options and associated designs includes:

- Define important process evaluation and selection criteria
- Assign weighting factors to each of the selection criteria
- Evaluate the process alternatives based on the selection criteria
- Define preliminary design criteria
- Collect, generate, and analyze pertinent characterization data
- Pilot plant studies (if necessary)
- Develop conceptual designs
- Assessment of life-cycle costs
- Benefit-cost analysis
- Detailed analysis and assessment of alternatives, including advantages and limitations, and pre-selection of most appropriate processes (i.e., as part of a Pre-design Report)
- Detailed design, pre-selection specifications, and bids upon project approval

For a proper evaluation of process alternatives, it is essential that a common basis for comparison is used and that life-cycle costing is included. The manufacturers should be required to provide information and guarantees on their equipment, including lamp life, lamp replacement and equipment costs, power consumption, and labour requirements for O&M. This is elaborated upon in **Chapter 7**.

Based on the evaluation of alternatives, the most suitable process can be selected and detailed system design developed with the assistance of an engineering consultant and the selected technology manufacturer.

7 Developing a Strategy

7.1 Basis for Design Comparisons

7.1.1 Required Information in UV System Bids

Manufacturers' bids for proposed UV systems should have clearly defined design bases and provide an adequate breakdown of components to enable a proper comparison of alternative systems. This is important in view of the various manufacturers and vendors of UV disinfection technologies and numerous unique process designs, configurations, and equipment that are commercially available. Evaluations of alternatives should be based on a common basis of comparison. Essential information includes:

- Design parameters (e.g., design minimum UV dose, lamp age factor, fouling factor)
- Summary of proposed system equipment (e.g., number and configuration of reactors, lamps, sensors, control system, instrumentation, ancillary components, etc.) and specifications
    - ➢ Include approximate dimensions of each channel and bank/reactor
- UV reactor performance validation data is desirable
    - ➢ To confirm reactor capabilities
- Hydraulic requirements and characteristics
    - ➢ Include information on headloss through the bank/reactor and channel at peak flow conditions
- Power requirements
    - ➢ Per lamp
    - ➢ Overall system
- Expected operation and maintenance requirements (i.e., labour)
- Expected effective life time of components (e.g., lamps and ballasts)
- Operational strategy (e.g., cleaning, system safeguards)
- Process control strategy (i.e., manual or automatic control)
- Cost information (equipment capital cost and replacement costs)
- Warranties (e.g., guaranteed life of equipment, UV lamps, ballasts)
- Reference list of similar previous applications

7.1.2 Components of UV System Specifications

System specifications from technology vendors should contain the following information:

- Critical design basis
    - ➢ Flow rates
    - ➢ Influent wastewater quality

  - ➢ Disinfected wastewater quality target
  - ➢ Minimum UV dose (i.e., under conservative system conditions)
- Outline of components included with the system (e.g., number and arrangement of UV banks and lamps, process on-line control and monitoring system, level control system, number of UV intensity monitors, alarm conditions, etc.)
- Hydraulic characteristics of the UV disinfection system (e.g., headloss, minimum pipe length requirements, spacing between banks of lamps, etc.)
- Other site specific characteristics (e.g., space constraints, desired degree of redundancy)
- Warranties (e.g., equipment, UV lamps, ballasts)

7.2 Preliminary Costing

Generic applications covering a range of WWTP sizes and treated effluent qualities were defined for the purposes of preliminary costing. For each application, information was requested from the major UV suppliers on the suitable UV disinfection system design for that application, the necessary equipment, and the capital and operating cost estimates. This information is intended to assist potential users of UV technology in identifying suitable process alternatives for the different applications. It is emphasized that this information is generic and preliminary in nature and that detailed designs and more accurate costing for actual applications will be site specific.

The six generic applications included three different flow rates and two levels of secondary treated effluent quality. The defined average flow rate conditions were as follows:

- Small sized plant with 5 MLD
- Medium sized plant with 35 MLD
- Large sized plant with 200 MLD

Each was based on a peaking factor of 2 (i.e. twice the average flow rate). Effluent characteristics for each include:

- Poor secondary effluent quality based on average effluent SS of 20 mg/L and UV transmittance of 50%
- Good secondary effluent quality based on average effluent SS of 10 mg/L and UV transmittance of 70%

Each major supplier provided the requested information. The costs included by each need to be confirmed by the reader and are provided here for information only. The reader needs to ensure that all items are provided in an actual site-specific bid to allow for a direct comparison. Included items should include:

- Spare parts, lamps, ballasts, wipers, etc.
- Lifting devices
- Level control devices
- Control systems and instrumentation

- Transformers
- MCC panels
- Misc. equipment

In addition all costs provided in the subsequent tables are for UV equipment only, costs for physical facilities including channels, buildings and all associated equipment would be extra and can range from 75 to 200 percent of the UV equipment costs (WERF, 1995). O&M costs are estimates provided by the manufacturer and include equipment (especially lamps) replacement and energy costs. Labour costs for operations and maintenance do not appear to be included.

Budgetary pricing provided for each scenario is provided in **Table 7-1** through **Table 7-6**. Each table provides the type of lamp and orientation, total number of lamps, power per lamp, capital cost, annual O&M, lamp life guarantee and cost per lamp. Tables are for increasing plant size, lower quality effluent followed by higher quality effluent. Some tables have five categories, others only three. For small facilities (i.e., 5 MLD average capacity or less), some manufacturers have recommended low pressure/low intensity systems both for horizontal and vertical installations. For larger plants (medium and large facilities), low pressure/low intensity systems were not recommended by any of the main manufacturers.

As indicated above, the design and costing of UV systems will be site specific and the best system for a given site will depend on many factors. Factors will include effluent quality, flow rates and site requirements, to name a few. However, the generic design and pricing information does provide some general information regarding systems for different flows and effluent qualities. For small plants, low pressure/low intensity systems (both vertical and horizontal orientations) appear to be very economical compared to low pressure/high intensity and medium pressure/high intensity systems. Medium pressure systems appear to be more cost effective for large facilities. The number of lamps is significantly reduced when using medium pressure/high intensity lamps or high wattage (Level 2) output low pressure/high intensity lamps. For a large plant with either poor or good secondary effluent quality MP/HI or high wattage (Level 2) LP/HI systems indicated 8 times fewer lamps on average than the regular wattage (Level 1) LP/HI systems. Lamp life also varies with different lamp types, LP/LI and normal wattage (Level 1) LP/HI lamps are generally guaranteed for 10,000 to 13,000 hours. MP/HI and high wattage (Level 2) LP/HI lamps have a shorter lamp life ranging from 5,000 to 8,760 hours.

The impact of effluent quality on the number of lamps required also varies between the various designs. Overall the number of additional lamps for a particular manufacturer for a poor secondary effluent versus a good secondary effluent varied from 170% for small plants to 190 to 200% for medium and large plants. Smaller plants may have benefited less from an improved effluent quality due to the fewer number of lamps used and the need to maintain regular sized banks and modules. For medium and large facilities MP/HI appear to have a higher ratio of lamps required for a poor quality effluent over a good quality effluent, averaging 210% when compared to the LP/HI at 180%.

The installed lamp power also varied based on the size of facility, effluent quality and type of lamp used. As expected due to the wider spectrum of light produced from MP/HI lamps, these systems had

Table 7-1 Budgetary Pricing for Small Sized Plant with Poor Secondary Effluent

Parameter	Lamp Type				
	MP/HI	LP/LI Vertical	LP/LI Horizontal	LP/HI Horizontal	LP/HI Vertical
Total Lamps	16	160	112	32 - 84	5 SLRs (single lamp reactor)
Power/Lamp	2.5 kW	75 W	87.5 W	200 - 330 W	1.62 kW
Capital Cost ($)	$162,000	$104,000	$82,000	$108,000 - $140,000	$143,900
Annual O & M Cost	$10,600	NA	$4,200	$5,100 - $9,100	$10,100
Lamp Life Guaranteed Hrs.	8,000	10,000	12,000	12,000	8,760
Cost/Lamp	$640	$65	$50	$145 - $260	$2,835

Note: Small plant with poor secondary effluent indicates 5 MLD average, 10 MLD peak, UVT of 50%, effluent TSS of 20 mg/L.

Table 7-2 Budgetary Pricing for Small Sized Plant with Good Secondary Effluent

Parameter	Lamp Type				
	MP/HI	LP/LI Vertical	LP/LI Horizontal	LP/HI Horizontal	LP/HI Vertical
Total Lamps	12	80	60	24 - 48	3 SLRs (single lamp reactor)
Power/Lamp	2.5 kW	75 W	87.5 W	200 - 330 W	1.62 kW
Capital Cost ($)	$129,600	$65,000	$56,000	$86,000 - $100,000	$97,400
Annual O & M Cost	$8,000	NA	$2,200	$3,600 - $5,200	$6,100
Lamp Life Guaranteed Hrs.	8,000	10,000	12,000	12,000	8,760
Cost/Lamp	$640	$65	$50	$145 - $260	$2,835

Note: Small plant with good secondary effluent indicates 5 MLD average, 10 MLD peak, UVT of 70%, effluent TSS of 10 mg/L.

the highest installed power of the systems reviewed, based on the generic submissions by the main manufacturers. Correcting the installed power to the size of plant was used as a means to compare the three sizes of facilities provided. **Figure 7.1** shows the results for each condition (plant size and effluent quality) and lamp type. For poor secondary effluent, MP/HI lamp systems provided between 7 and 9 kW/MLD of installed power per average flow rate. In contrast LP/LI and LP/HI systems were provided with between 2 and 2.5 kW/MLD for a poor secondary effluent. The trend is the same for a good quality secondary effluent with MP/HI systems providing 3.5 to 6.0 kW/MLD, compared to 1.1 to 1.5 kW/MLD for LP/LI or LP/HI lamps. It should be noted that the installed power is based on the total number of lamps installed, although they will not always be in use and may be modulated for

Table 7-3 Budgetary Pricing for Medium Sized Plant with Poor Secondary Effluent

Parameter	Lamp Type		
	MP/HI	LP/HI Horizontal	LP/HI Vertical
Total Lamps	72	216 - 576	34 SLRs -720
Power/Lamp	4.5 kW	200 - 330 W	165 W - 1.62 kW
Capital Cost ($)	$955,800	$546,000 - $800,000	$667,500 - $685,000
Annual O & M Cost	$73,500	$33,500 - $62,300	$68,600
Lamp Life Guaranteed Hrs.	8,000	12,000	8,760 - 13,000
Cost/Lamp	$800	$145 - $260	$105 - $2,835

Note: Medium plant with poor secondary effluent indicates 35 MLD average, 70 MLD peak, UVT of 50%, effluent TSS of 20 mg/L.

Table 7-4 Budgetary Pricing for Medium Sized Plant with Good Secondary Effluent

Parameter	Lamp Type		
	MP/HI	LP/HI Horizontal	LP/HI Vertical
Total Lamps	32	216 - 576	21 SLRs -240
Power/Lamp	4.5 kW	200 - 330 W	165 W - 1.62 kW
Capital Cost ($)	$469,800	$330,000 - $568,000	$398,500 - $495,400
Annual O & M Cost	$32,700	$23,100 - $34,600	$42,300
Lamp Life Guaranteed Hrs.	8,000	12,000	8,760 - 13,000
Cost/Lamp	$800	$145 - $260	$105 - $2,835

Note: Medium plant with good secondary effluent indicates 35 MLD average, 70 MLD peak, UVT of 70%, effluent TSS of 10 mg/L.

some systems. Some systems may control or modulate power more effectively, which will impact lamp life and overall system electrical costs. When considering **Figure 7.1**, note that the installed lamp power is just one aspect of the total O&M costs. See **Sections 3.5.1 and 5.2.2.2** for more information on O&M costs.

As indicated earlier the O&M costs provided as part of the generic pricing have not been verified for completeness and for what was or was not included by each manufacturer. Some submissions did indicate labour costs for lamp and wiper replacement, others did not or were unclear. A review of the partial O&M costs for operating each system was undertaken by assuming a uniform operating condition. The partial O&M costs were calculated to account for electrical consumption costs (i.e. no demand charges) and lamp replacement. The costs were estimated for each condition (i.e. flow and effluent quality) and lamp type/manufacturer by assuming each operated 50% of the quoted lamps at 100% output. It was assumed that each manufacturer provided enough capacity to treat the peak flows

Table 7-5 Budgetary Pricing for Large Sized Plant with Poor Secondary Effluent

Parameter	Lamp Type		
	MP/HI	LP/HI Horizontal	LP/HI Vertical
Total Lamps	360 - 440	1296 - 3200	194 SLRs - 3200
Power/Lamp	2.8 - 4.5 kW	200 - 330 W	165 W - 1.62 kW
Capital Cost ($)	$2,682,000 - $4,698,000	$3,470,000 - $4,100,000	$4,147,000 - $4,247,900
Annual O & M Cost	$367,700 - $404,800	$200,800 - $346,000	$391,200
Lamp Life Guaranteed Hrs.	5,000 - 8,000	12,000	8,760 – 13,000
Cost/Lamp	$250 - $800	$145 - $260	$105 - $2,835

Note: Large plant with poor secondary effluent indicates 200 MLD average, 400 MLD peak, UVT of 50%, effluent TSS of 20 mg/L.

Table 7-6 Budgetary Pricing for Large Sized Plant with Good Secondary Effluent

Parameter	Lamp Type		
	MP/HI	LP/HI Horizontal	LP/HI Vertical
Total Lamps	160 - 240	864 - 1920	120 SLRs -1440
Power/Lamp	2.8 - 4.5 kW	200 - 330 W	165 W - 1.62 kW
Capital Cost ($)	$1,465,400 - $2,592,000	$2,460,000 - $2,480,000	$1,924,000 - $2,660,300
Annual O & M Cost	$163,400 - $222,200	$133,800 - $207,600	$242,000
Lamp Life Guaranteed Hrs.	5,000 - 8,000	12,000	8,760 – 13,000
Cost/Lamp	$250 - $800	$145 - $260	$105 - $2,835

Note: Large plant with good secondary effluent indicates 200 MLD average, 400 MLD peak, UVT of 70%, effluent TSS of 10 mg/L.

and therefore on average half the lamps would be in operation. Lamp replacement was based on the ratio of the operating hours (i.e. full time operation of 8736 hours/year) to the lamp guarantee hours. Electrical costs were based on a power cost of $0.06 per KWh. Electrical costs were based on having 50% of the lamps in operation at 100% of their rated power draw.

An example calculation of the partial O&M costs follows. If the provided design called for 200 lamps at 200 W rated power draw, a lamp guarantee of 10,000 hours and a replacement cost of $100/lamp, it would be assumed that 100 lamps were in operation continuously on a yearly basis. Therefore, 100 lamps at 200 KW power draw, would result in a power consumption of 174,720 KWh/year (i.e. 100 lamps x 200 W / 1000 KW/W x 8736 hours/year). At $0.06/KWh, this would result in a power consumption charge of $10,483. Lamp replacement would be based on 100 lamps utilized for 87% of

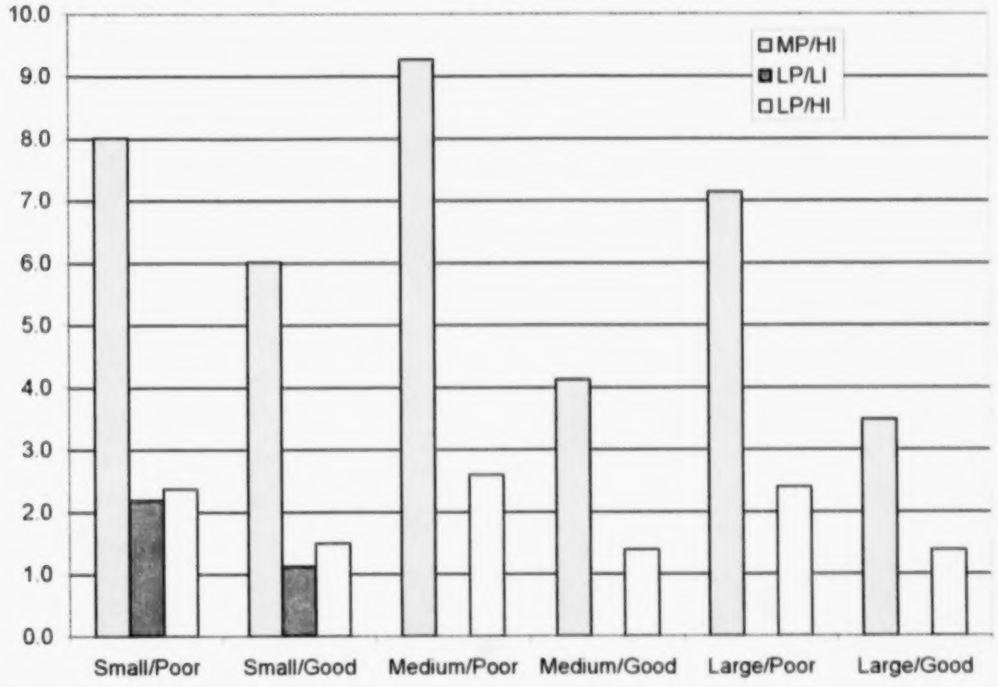

Figure 7.1 **Comparison of Installed Lamp Power for Different Size Facilities and Effluent Qualities**

their guaranteed life (i.e. 8,736 hours of 10,000 hour guaranteed life). Therefore, the lamp replacement cost prorated for the year would be 87% of the $100/lamp for the 100 lamps in operation or $8,736. Total partial O&M for this example would be $19,219.

Each submission was analyzed using the method outlined above and the results of this analysis are summarized in **Figure 7.2** for each size plant (i.e. small 5 MLD, medium 35 MLD and large 200 MLD), effluent quality (i.e. poor and good) and lamp type (LP/LI, LP/HI and MP/HI). The results are close to the reported O&M costs provided by the manufacturers for the LP/HI lamps. A comparison of the calculated and provided O&M costs varied from 89 to 108% for the LP/HI for the six scenarios, averaging 98% for all scenarios. The calculated partial O&M cost for the LP/LI was on average 45% higher than the provided costs, most probably because one the suppliers did not provide O&M costs. The MP/HI calculated partial O&M costs were higher than provided for by the manufacturers for all cases, varying from 50% higher for the small and medium size plant conditions to 25% for the large plant. The large plant provided O&M costs were based on two manufacturers, whereas the other cases were based on only one.

Figure 7.2 shows the relatively similar cost for each flow and effluent quality, after the results are unitized by flow rate. Poor secondary effluent generally required 80% higher O&M costs (partial) over a good secondary effluent. Medium pressure systems required 85% higher partial O&M costs based on

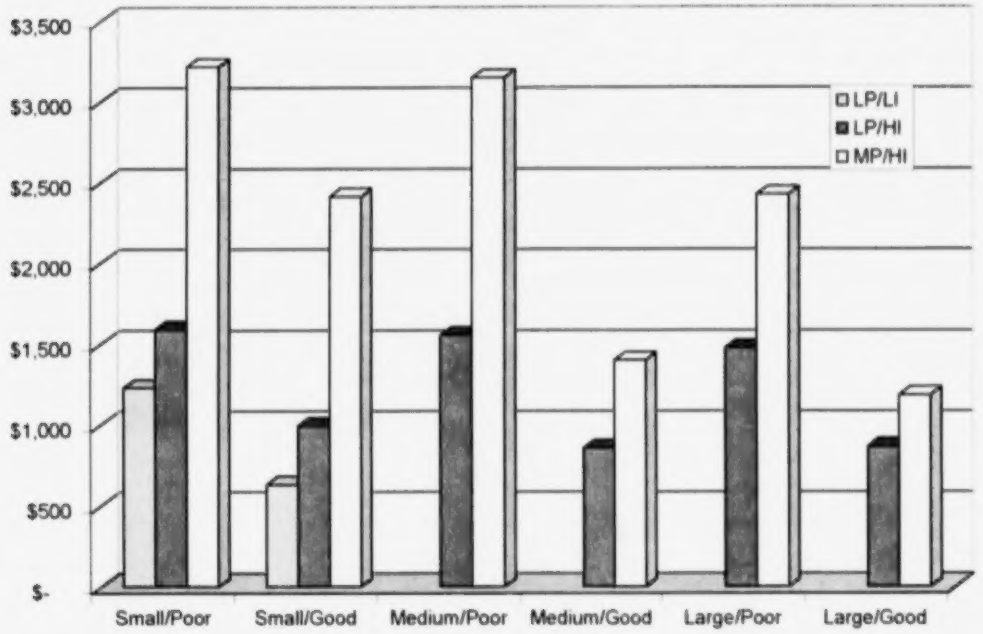

Figure 7.2 Calculated Partial O&M Costs for Each Scenario and Lamp Type

the method used above. However, this method assumes 100% output for all systems and this is not necessarily the operating method that would be used.

The following evaluation is for information only and was used to highlight the potential electrical and lamp replacement costs for each system operated in a similar manner. Actual UV system operations will vary for the different systems and conditions. As part of the specification or pre-selection process the designer should indicate the evaluation method to be used, including the means for calculating the O&M costs such that all manufacturers are aware of the method being used.

Overall, the generic design and costs indicate that all type of lamps can be applied to a variety of applications, in terms of plant size and secondary effluent quality. For the main manufacturers that provide LP/LI lamps, this type of lamp was only put forward for the small facility application. For the large plant application two manufacturers put forward a design with MP/HI lamps.

8 Conclusions/Recommendations

8.1 Conclusions

This manual provides an overview of UV technology and advancements based on a review of recent relevant literature sources and input from UV system manufacturers and users. The manual consolidates key planning, process selection, design, operation, and cost information for UV disinfection installations at wastewater treatment plants (WWTPs) in Canada. The manual provides guidance to engineers, scientists, and wastewater treatment plant operators. This manual concentrates on UV disinfection of secondary activated sludge wastewater treatment plant effluents. However, the manual also presents considerations for other plant effluents. The main conclusions from the manual report are:

- Ultraviolet (UV) irradiation is a viable, economical option for disinfection of secondary wastewater effluents.
- The technology has been available since the early 1920's but has only been applied for full-scale wastewater applications commercially since around 1980.
- The germicidal UV light wavelength range is from 250 to 270 nm; the optimal wavelength is 265 nm. Low pressure lamps emit essentially monochromatic UV light at 253.7 nm. Medium pressure lamps emit polychromatic radiation.
- UV dose determines disinfection effectiveness. Dosage is a function of UV intensity and exposure time.
- Factors impacting UV disinfection performance include:
  - UV light intensity
  - Exposure time
  - Wastewater characteristics (including transmittance, suspended solids, and constituents that can foul UV lamp sleeves)
- Algae interference with the UV lamps is a problem at many plants causing either excessive maintenance and/or reduced efficiency. Automatic wipers are not expected to be effective against stringy algae that can accumulate through the reactor.
- Three major lamps are available for disinfection including low pressure/low intensity (LP/LI), low pressure/high intensity (LP/HI), and medium pressure/high intensity (MP/HI). LP/HI lamps are available in a wide range of lamp wattages. For this manual, lamps with wattages of less than 500 W are referred to as Level 1 (or L1) and those above as Level 2 (or L2).
- Low pressure lamps emit the majority of their UV output at 253.7 nm; medium pressure lamps emit a wide spectrum of UV light from 200 nm to near 600 nm.
- Low pressure/low intensity lamps are the most efficient at converting their input energy to germicidal UV light. Medium pressure lamps are the least efficient. Medium pressure lamps produce more germicidal UV light per lamp than most low-pressure lamps but require a higher level of input power.

- High intensity lamps are usually equipped with automatic cleaning systems due to the high lamp temperatures, which may promote lamp sleeve fouling.
- Low-pressure lamps (low and high intensity) last longer than medium pressure lamps.
- Low pressure/low intensity UV disinfection systems are normally used in small to medium-sized municipal wastewater treatment plants. Low pressure/high intensity UV systems are used in small to large-sized plants. Medium pressure/high intensity UV systems are normally used in medium to large-sized plants.
- Ballasts are an important component of a UV disinfection system. Electronic and electromagnetic ballast designs are available. Electronic ballasts are more common in newer systems.
- Reactors are either open channel or closed chamber systems. Lamps are mounted either horizontally or vertically.
- Hydraulics should be considered to ensure that the wastewater can flow through the reactor and that the lamps are maintained in proper contact with the wastewater.
- Controls vary for different systems but can include:
  - Status of individual lamps and ballasts
  - System power
  - System time
  - Flow rate (usually inputted into controller from plant instrumentation)
  - UV intensity within reactor
  - Water level in reactor
  - UV Transmittance (generally optional)
  - Turbidity or suspended solids online (generally optional)
- Capital costs can vary greatly. They depend not only on the peak flow to be treated and the target effluent limits, but also the wastewater characteristics. Operational and maintenance costs can vary for different systems, including lamp replacement costs/operating hours and electrical costs, and need to be carefully considered when evaluating different systems.
- Many manufacturers/suppliers provide UV systems, but only a few are experienced with wastewater applications in North America. These include:
  - Aquionics
  - ONDEO Degremont
  - Suntec *environmental*
  - Trojan Technologies
  - UV Systems Technology Inc./Ultra Guard

  - UV Systems Technology has recently given the rights to manufacture the Ultra Guard UV product line to BCA the Clearwater Group, British Columbia; USFilter markets and supplies the product line in North America

- WEDECO–Ideal Horizons
  - Some manufacturers provide a single technology for UV disinfection while others provide multiple types of reactors and lamps for different applications. Ultra Guard provides a single lamp and orientation for all UV applications. Some manufacturers use low pressure/high intensity lamps exclusively including Ultra Guard and Suntec *environmental*. Aquionics uses medium pressure/high intensity lamps. ONDEO Degremont uses low pressure lamps but offers both low and high intensity output. Trojan Technologies and WEDECO–Ideal Horizons offer all three types of lamps with their various systems, although WEDECO more actively markets their open channel systems with low pressure/high intensity lamps.

- Many factors need to be considered when choosing a UV system for a particular site. Issues such as site conditions, effluent characteristics, compliance requirements, plant hydraulics and layout etc. need to be considered.
- A complete list of screening criteria has been provided for review for all UV installations. A preliminary decision-tree was developed to assist in suggesting an appropriate UV technology for a given site and considerations. Additional criteria items are also provided for consideration by the user of the manual.
- Two example applications for illustration of the preliminary decision-tree procedure with additional criteria discussion are provided. These examples are for a new installation and a potential retro-fit application.
- For a proper evaluation of competing UV disinfection technologies, it is essential that a common basis for comparison is used and that life-cycle costing is included.
- Generic pricing for a range of plant sizes from small to large and with poor or good secondary effluent quality was obtained for comparison. Issues such as impact of effluent quality and UV transmittance, lamp life, plant size and installed power requirements are discussed for each lamp type.

8.2 Recommandations

The following recommendations are made from this manual:

- That UV technology is an important and applicable technology for wastewater effluent disinfection applications, and should be considered strongly.
- There are many UV manufacturers with equipment that is applicable for multiple applications, alternative designs, and lamps that should be considered.

This manual's purpose is to provide information and guidance to communities investigating UV technologies for applications at their wastewater plants. Criteria and tools provided are to assist in the initial evaluation of the issues and the preliminary selection of UV technologies. At this point additional engineering consultation and manufacturer input should be obtained to develop the best system for a particular installation.

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Appendix A
Manufacturer's Summary Sheets

Date:	Nov. 28, 2001	Phone Number:	905-528-3807
Contact:	Brian Gage	Fax Number:	905-528-3429
Supplier:	Aqua Technical Sales	Email:	bgage@attglobal.net

Manufacturer:	ONDEO-degremont usa	Contact:	Arthur Shapiro
Website:	Degremont-usa.com	Email:	ShapiroA@ondeodegremont-usa.com

UV Equipment:
Type of System (lamp, orientation, configuration):
Vertical lamp format, 40 lamp module reactor, low pressure lamps, low and high intensity available
Years in business (with UV):
Offering UV since 1992, high intensity in last 2 years
System Description:
Vertical lamp, flow paced modules, lamp seals above water, indivudal lamp removal, user friendly/ complete controls SCADA
Limiting Parameters (max. flow, sizing, units):
Open channel, low intensity for smaller systems
O&M Requirements:
Cleaning systems available, air purge; wipers on high intensity; O&M limited need with automatic cleaning
Installation Sites (& sites to visit):
Barrie (low intensity) and plant in Ohio (high intensity)
Other Comments:
Info on Equipment (brochures, etc.):
Brochures on each system
Technical and/or Research Papers:

GENERAL			
Manufacturer	Ondeo Degremont	System	Aquaray 40 VLS and HO VLS*
Years in business	10	Suppliers	ATSI
UV EQUIPMENT			
Recommended UV dose	> 30 mJ/cm^2	Flow rate limitation	
Lamps per reactor	40	Type of lamp	Low pressure-high output (intensity)
Configuration	Open channel, banks	Mounting	Vertical, single-ended
Power consumption	6 kW/reactor	Size of standard reactor	24" x 30" foot print
Lamp operating life	13 000 h	Plant size application	Full range
Germicidal UV production		Ballast location	NEMA 4X enclosure
Special Features	Vertical, flow paced modules		
MONITORING EQUIPMENT			
Online monitoring available	Yes	Recommended monitoring	PLC – UV intensity
Available controls	PLC	Variable output capability	Flow pacing by 8 lamp row
CLEANING MECHANISM			
Automatic or manual	Auto	Frequency	3-4 x daily
If automatic, type	Air purge (both), wiper (HO)	Mechanical or chemical	Mechanical only
REFERENCES			
Validation/certification protocols	NWRI Title 22	Number of installations and sizes	> 300
Operating years at sites	> 10 years	Similar sites	Barrie
COSTS			
Capital cost for various sizes		Operating and maintenance costs	
Chemicals (automatic cleaning)		Lamp replacement costs	
MISC.			
Mercury content of system	< 20 μg	Operating temperature	65°C
Maximum ambient humidity	80% RH	Fouling rate	Site specific
Head loss per bank	< 2"	Required contact time	5 seconds
Means of level control	Baffle type	Pretreatment requirements	
Serviceability	Superior	Availability of pilot plant	500 gpm @ $8000/month

Date:	Dec. 5, 2001	Phone Number:	856-507-4144
Contact:	Bernard Dussert	Fax Number:	856-507-4079
Supplier:	US Filter/Wallace & Tiernan	Email:	bdussert@usfwt.com

Manufactuer:	UV Systems Tech	Contact:	Peter Colak 1-800-801-5656
Website:	www.ultraguard.com	Email:	pzcolak@msn.com; fax 604-899-8967 info@ultraguard.com

UV Equipment:

Type of System (lamp, orientation, configuration):

Vertical mounted, low pressure/high intensity

Years in business (with UV):

1995 development, 1998 first order

System Description:

Low pressure, ultra-high intensity (1620 W input/504 W output)

Limiting Parameters (max. flow, sizing, units):

100 to 800 gpm/lamp (550 m^3/d and up)

O&M Requirements:

Installation Sites (& sites to visit):

Peterborough

Other Comments:

New system one lamp reactor for 1 mgd

Info on Equipment (brochures, etc.):

Info – brochure, description, reference listed, Peterborough rept/eval.

Technical and/or Research Papers:

Abstract for WEFTEC 2001

GENERAL			
Manufacturer	Ultra Guard	System	Ultra Guard
Years in business	6	Suppliers	US Filter/Wallace & Tiernan
UV EQUIPMENT			
Recommended UV dose	15-30 mJ/cm^2	Flow rate limitation	1 mgd per lamp
Lamps per reactor	Varies, as few as one.	Type of lamp	Low pressure/high intensity
Configuration	Vertical	Mounting	Vertical
Power consumption	1620 W	Size of standard reactor	Open channel
Lamp operating life	8760 – 2,000 h, 5000 h guaranteed to 12000 if paced	Plant size application	Full range
Germicidal UV production	504 W	Ballast location	In MCC; new are submerged
Special Features	SLR, individual reactors, upstream diffuser plate		
MONITORING EQUIPMENT			
Online monitoring available	Intensity meter	Recommended monitoring	
Available controls	Inlet gate/transmittance	Variable output capability	50-100% med + # SLRs
CLEANING MECHANISM			
Automatic or manual	Automatic (mech/c level	Frequency	Variable: # / h
If automatic, type	Mechanical cleaner	Mechanical or chemical	Both
REFERENCES			
Validation/certification protocols		Number of installations and sizes	<10, 32 mgd peak largest
Operating years at sites	3 years	Similar sites	Peterborough
COSTS			
Capital cost for various sizes		Operating and maintenance costs	
Chemicals (automatic cleaning)		Lamp replacement costs	
MISC.			
Mercury content of system	0.2 g	Operating temperature	60 to 140°C
Maximum ambient humidity		Fouling rate	
Head loss per bank	5 to 12 inches (125 to 300 mm)	Required contact time	
Means of level control		Pretreatment requirements	
Serviceability		Availability of pilot plant	Yes, single lamp full scale

Date:	Dec. 4, 2001	Phone Number:	(905) 669-4450 (Ext. 243)
Contact:	Doug Reed	Fax Number:	(905) 669-4451
Supplier:	Suntec *environmental*	Email:	dreed@suntecuv.com

Manufactuer:	Suntec *environmental*	Contact:	As above
Website:	www.suntecuv.com	Email:	As above

UV Equipment:

Type of System (lamp, orientation, configuration):

Horizontal mounted, low pressure/high intensity

Years in business (with UV):

Started in 1998; first installation in 2000; first installation by parent company Photoscience Japan, 1993

System Description:

LPX Series systems; low pressure, high intensity with 200 W and 500 W lamps commercially available; flow/dose pacing option

Limiting Parameters (max. flow, sizing, units):

300 lpm 200-W lamp, 750 lpm per 500-W lamp; systems sizes of 380+ MLD (100+ USmgd)

O&M Requirements:

Low maintenance system; low O&M requirements with optional PLC-based system control center

Installation Sites (& sites to visit):

14 installations currently worldwide; Deseronto, Ontario WWTP has longest operating experience

Other Comments:

Technical representatives have numerous years of UV disinfection experience related to R&D, engineering, design, manufacturing and sales.

Info on Equipment (brochures, etc.):

Info – brochures, CD and product binder with system specifications, list of installations at WWTPs

Technical and/or Research Papers:

Numerous technical papers were provided by Dr. Elliot Whitby, Research Director at Suntec

Windsor UV Feasibility and Guidance Manual Project Telephone Interview Record

GENERAL			
Manufacturer	Suntec *environmental*	System	LPX200
Years in business	3 years	Suppliers	Suntec *environmental* & ACI Instrumentation
UV EQUIPMENT			
Recommended UV dose	> 30 mJ/cm^2	Flow rate limitation	300 lpm per lamp; 0- 3 MLD for packaged plant
Lamps per reactor	2 – 16 per rack (module)	Type of lamp	Low pressure / high intensity
Configuration	Lamps horizontal and parallel to flow	Mounting	Racks suspended in open channel; package is closed
Power consumption	210 W per lamp nominal (including ballast)	Size of standard reactor	2 banks in series; 8.0 m x 0.7 m x 1.2 m (LxWxH)
Lamp operating life	> 12,000 hours	Plant size application	0 – 110 MLD; LPX500 for larger applications
Germicidal UV production	Average 65 W UVC at 254 nm, after 100 hours	Ballast location	Submerged ("cooled by configuration")
Special Features	Self-cooling submersible electronic ballast; variable output lamps; coated lamp for longer life; automatic wiper with simple electric drive		
MONITORING EQUIPMENT			
Online monitoring available	UV intensity, flow rate	Recommended monitoring	Site specific; UVT monitoring
Available controls	Optional advanced control system available; flow/dose pacing, remote control with PLC host	Variable output capability	Available as an option; 50-100% range
CLEANING MECHANISM			
Automatic or manual	Automatic	Frequency	Once per hour or less
If automatic, type	Programmable; electric motor driven	Mechanical or chemical	Mechanical; stainless steel wire
REFERENCES			
Validation/certification protocols	Planned for near future; Hydroqual bioassay (NSF)	Number of installations and sizes	14 systems installed; 22 systems total by June 2002
Operating years at sites	> 2	Similar sites	0.8–60 MLD peak flows; 190 MLD system in 2002
COSTS			
Capital cost for various sizes	Not yet available	Operating and maintenance costs	Not yet available

Chemicals (automatic cleaning)	Not applicable	Lamp replacement costs	$145 CDN per 200 W lamp
MISC.			
Mercury content of system	5 mg per lamp	Operating temperature	100°C
Maximum ambient humidity	Not a factor; small heater and NEMA 4X enclosed	Fouling rate	Site specific; minimized by automatic cleaning
Head loss per bank	< 32mm at peak flow rate through one bank	Required contact time	Approximately 6 seconds
Means of level control	Automatic level control gate or serpentine weir	Pretreatment requirements	Not necessary for secondary treated effluent
Serviceability	Low maintenance system	Availability of pilot plant	$2-3 K/month (Cdn); packaged plant with 4 lamps

Windsor UV Feasibility and Guidance Manual Project Telephone Interview Record

GENERAL			
Manufacturer	Suntec *environmental*	System	LPX500
Years in business	3 years	Suppliers	Suntec *environmental* & ACI Instrumentation
UV EQUIPMENT			
Recommended UV dose	> 30 mJ/cm^2	Flow rate limitation	760 lpm per lamp maximum
Lamps per reactor	2 – 8 per rack (module)	Type of lamp	Low pressure / high intensity
Configuration	Lamps horizontal and parallel to flow	Mounting	Racks suspended from brackets into open channel
Power consumption	510 W per lamp nominal (including ballast)	Size of standard reactor	2 banks in series; 8.0 m x 0.7 m x 1.7 m (LxWxH)
Lamp operating life	> 12,000 hours	Plant size application	20 – 380+ MLD
Germicidal UV production	Average 150 W UVC at 254 nm, after 100 hours	Ballast location	Submerged ("cooled by configuration")
Special Features	Self-cooling submersible electronic ballast; variable output lamps; coated lamp for longer life; automatic wiper with simple electric drive		
MONITORING EQUIPMENT			
Online monitoring available	UV intensity, flow rate	Recommended monitoring	Site specific; UVT monitoring
Available controls	Optional advanced control system available; flow/dose pacing, remote control with PLC host	Variable output capability	Available as an option; 50-100% range
CLEANING MECHANISM			
Automatic or manual	Automatic	Frequency	Once per hour or less
If automatic, type	Programmable; electric motor driven	Mechanical or chemical	Mechanical; stainless steel wire
REFERENCES			
Validation/certification protocols	Planned for near future; Hydroqual bioassay (NSF)	Number of installations and sizes	None presently; full scale demos in near future
Operating years at sites		Similar sites	
COSTS			
Capital cost for various sizes	Not yet available	Operating and maintenance costs	Not yet available

Chemicals (automatic cleaning)	Not applicable	Lamp replacement costs	$290 CDN per 500 W lamp
MISC.			
Mercury content of system	12 mg per lamp	Operating temperature	100°C
Maximum ambient humidity	Not a factor; small heater and NEMA 4X enclosed	Fouling rate	Site specific; minimized by automatic cleaning
Head loss per bank	< 32mm at peak flow rate through one bank	Required contact time	Approximately 6 seconds
Means of level control	Automatic level control gate	Pretreatment requirements	Not necessary for secondary treated effluent
Serviceability	Low maintenance system	Availability of pilot plant	$2-3 K/month (Cdn); LPX200 packaged plant

Windsor UV Feasibility and Guidance Manual Project Telephone Interview Record

Date:	Dec. 3, 2001	Phone Number:	(905) 777-9494
Contact:	George Pastoric	Fax Number:	(905) 777-8678
Supplier:	Hydro-Logic Environmental	Email:	george@hydrologic.ca

Manufactuer:	AQUIONICS Inc.	Contact:	Robert Grob (Director of Engineering)
Website:	www.aquionics.com	Email:	rob@aquionics.com

UV Equipment:

Type of System (lamp, orientation, configuration):

Medium pressure/high intensity lamps mounted horizontally into wastewater pipelines; "Inline" and "Closed Channel" Series available; lamps are perpendicular to flow

Years in business (with UV):

Eighteen (18) years; earliest installation shown in North American site references list is 1988

System Description:

The Inline and Closed Channel systems are installed into effluent pipelines; medium pressure, high output lamps between 2 to 4 kW are used; 7.5 kW lamps are also available; automatic cleaning system; flow-and dose-pacing possible

Limiting Parameters (max. flow, sizing, units):

38 MLD (10 USmgd) typical maximum flow for the largest reactor (24 lamps); system sizes of up to 760 MLD (200 mgd)

O&M Requirements:

Low O&M requirements due to minimal number of components and automatic cleaning system; effective chamber design for ease of access for lamp replacement

Installation Sites (& sites to visit):

Approximately 100 in the U.S.; three large installations in Georgia practice year-round disinfection (i.e., candidates for site visits)

Other Comments:

The very high energy output allows for compact systems; Aquionics (in conjuction with sister companies Hanovia, UK and Berson, BV) are the only companies to develop and manufacture their own lamps

Info on Equipment (brochures, etc.):

Info – brochures, CD with equipment specifications and presentations, list of installations at WWTPs

Technical and/or Research Papers:

Windsor UV Feasibility and Guidance Manual Project Telephone Interview Record

GENERAL			
Manufacturer	Aquionics Inc.	System	"Inline" Series
Years in business	18	Suppliers	Berson (The Netherlands)
UV EQUIPMENT			
Recommended UV dose	25mJ/cm^2 – 100mJ/cm^2 depending on permit	Flow rate limitation	Up to 760 MLD; ~38 MLD per reactor (24-lamp)
Lamps per reactor	From 3 to 24	Type of lamp	Medium pressure / high intensity
Configuration	Closed vessel, inline; reactors typically in parallel	Mounting	Lamps perpendicular to flow; within pipe section
Power consumption	2 kW to 4 kW per lamp; to 5 kW incl. transformer	Size of standard reactor	8" to 30" flanges standard sizes
Lamp operating life	8000 hours	Plant size application	4 to 760 MLD (1 to 200 USmgd)
Germicidal UV production	Approximately 18%	Ballast location	Up to 100 meters remote from reactors
Special Features	Automatic cleaning system, gravity or pressure flow, compact footprint, minimal number of lamps, 20 year design life lamp power supplies		
MONITORING EQUIPMENT			
Online monitoring available	Yes	Recommended monitoring	One UV monitor per bank of lamps
Available controls	Microprocessor or PLC	Variable output capability	Three distinct power levels; 50% to 100%
CLEANING MECHANISM			
Automatic or manual	Both available, automatic cleaning standard	Frequency	Variable from 6 times per hour to once per day
If automatic, type	Electric motor driven lead screw	Mechanical or chemical	Mechanical standard; chemical feed optional
REFERENCES			
Validation/certification protocols	California Title 22 (NWRI)	Number of installations and sizes	Approximately 100; range from 0.4 to 450 MLD
Operating years at sites	Up to 15	Similar sites	Many using same model equipment
COSTS			
Capital cost for various sizes	$25K (US) per mgd estimate depending on design	Operating and maintenance costs	Depends on operation. Primarily power and lamps
Chemicals (automatic cleaning)	5% HCL or citric acid	Lamp replacement costs	Approx. $525 (US) for 4 kW, $375 for 2 kW lamp

MISC.			
Mercury content of system	Approximately 200 mg per lamp	Lamp operating temperature	Quartz sleeve at 600°C but wastewater cooled
Maximum ambient humidity	90%	Fouling rate	Minimal due to automatic cleaning
Head loss per bank	Varies, usually designed for less than 24 inches	Required contact time	Less than 1 second
Means of level control	Not applicable	Pretreatment requirements	None; applicable to primary, secondary, or tertiary treated effluents
Serviceability	Easy due to minimal number of components	Availability of pilot plant	3.8 MLD capacity; $0.5-1 K (US)/ month rental

Windsor UV Feasibility and Guidance Manual Project Telephone Interview Record

Date:	Dec. 3, 2001	Phone Number:	(416) 503-7639
Contact:	Edward Pikovnik	Fax Number:	(416) 503-8925
Supplier:	ENV Treatment Systems Inc.	Email:	envinc@interlog.com

Manufactuer:	WEDECO - Ideal Horizons	Contact:	Nathan Myers
Website:	www.wedecouv.com	Email:	nmyers@wedecouv.com

UV Equipment:

Type of System (lamp, orientation, configuration):

Horizontally-mounted, low pressure/high intensity

Years in business (with UV):

25 years

System Description:

TAK Series uses 300-W lamps; variable lamp output (50-100%); accurate flow/dose pacing; automatic wiping system; UV intensity sensor in module

Limiting Parameters (max. flow, sizing, units):

Modular design for practically unlimited flow capacities; largest installation in the world in New Zealand

O&M Requirements:

Highly automated, low maintenance system; low O&M costs owing to high energy output and very long lamp life

Installation Sites (& sites to visit):

68 installations in North America since 1997; 4.5 MLD capacity facility in Port Burwell, Ont.; a number of 50+ MLD installations in the U.S.

Other Comments:

A world leader in the development and manufacturing of advanced UV disinfection technologies for wastewater and drinking water applications. Have MP/HI process for disinfection of primary effluents.

Info on Equipment (brochures, etc.):

Info – brochures, list of installations at WWTPs

Technical and/or Research Papers:

Windsor UV Feasibility and Guidance Manual Project Telephone Interview Record

GENERAL			
Manufacturer	WEDECO – Ideal Horizons	System	TAK 55
Years in business	25	Suppliers	ENV Treatment Systems Inc.
UV EQUIPMENT			
Recommended UV dose	35 mJ/cm^2 (case-specific)	Flow rate limitation	Practically unlimited flow capacity; modular design
Lamps per reactor	2 – 20 per module	Type of lamp	Low pressure / high intensity
Configuration	Lamps horizontal and parallel to flow	Mounting	Modules with horizontal lamps fit into open channel
Power consumption	300 W per lamp	Size of standard reactor	Typically 2 banks in series; parallel channels
Lamp operating life	Guaranteed 12,000 hr (fixed); 15,000+ hr (var. out)	Plant size application	Practically unlimited owing to modular design
Germicidal UV production	125 W UV-C at 254 nm	Ballast location	Electrical cabinet; must be within 7.5 m of lamp
Special Features	Electronic ballasts; variable output lamps; automatic wiper system; accurate dose/flow pacing based on UV intensity; high degree of automation		
MONITORING EQUIPMENT			
Online monitoring available	UV intensity, flow rate	Recommended monitoring	On-line UVT monitoring
Available controls	Advanced PLC-based control system; can be connected to SCADA; flow/dose pacing	Variable output capability	Between 50-100%; infinitely variable (stepless)
CLEANING MECHANISM			
Automatic or manual	Automatic	Frequency	Adjusted by using PLC control
If automatic, type	PLC-controlled; compressed air driven	Mechanical or chemical	Mechanical wiping with teflon ring
REFERENCES			
Validation/certification protocols	Independent 3rd party verification of lamp output	Number of installations and sizes	68 in N.A.; World's largest in NZ at 1210 MLD
Operating years at sites	>20	Similar sites	All using TAK Series; most with automatic wiping
COSTS			
Capital cost for various sizes	Not yet available	Operating and maintenance costs	Not yet available

Chemicals (automatic cleaning)	Not applicable	Lamp replacement costs	$160 (US) per lamp (with purchase of >50 pieces)
MISC.			
Mercury content of system	Amalgam (solid state Hg); 150 mg/L	Lamp temperature	110 - 130°C
Maximum ambient humidity	80-100% depending on ballast enclosure	Fouling rate	Minimized or eliminated by automatic wiping
Head loss per bank	0.5 to 1.0"	Required contact time	Case specific; approximately 5 seconds
Means of level control	Automatic level control (case-specific design)	Pretreatment requirements	Not necessary for secondary treated effluent
Serviceability	Low maintenance system due to high automation	Availability of pilot plant	Yes; availability and price is case-specific

Windsor UV Feasibility and Guidance Manual Project Telephone Interview Record

Date:	Nov. 29, 2001	Phone Number:	(905) 264-2188 (Ext. 28)
Contact:	Ed Broeders	Fax Number:	(905) 264-2062
Supplier:	H2Flow Equipment Inc.	Email:	ed@h2flow.com

Manufactuer:	Trojan Technologies Inc.	Contact:	Allan Gates
Website:	www.trojanuv.com	Email:	agates@trojanuv.com

UV Equipment:
Type of System (lamp, orientation, configuration):
Horizontally-mounted, low pressure/low intensity, low pressure/high intensity and medium pressure/high intensity lamp technologies available (i.e., System UV3000, UV3000Plus, and UV4000, respectively)
Years in business (with UV):
25 years
System Description:
All three systems available for wastewater UV disinfection involve installation of lamp modules into open channels, parallel to the gravity flow; dose and/or flow-pacing capabilities; various options available
Limiting Parameters (max. flow, sizing, units):
Numerous systems and models available, covering the full range of wastewater disinfection applications (i.e., various wastewater types; small to very large flow systems)
O&M Requirements:
Relatively low O&M requirements for the automated System UV3000Plus (with options) and UV4000
Installation Sites (& sites to visit):
Over 2500 wastewater installations internationally; numerous WWTPs in Southern Ontario utilizing Trojan's all lamp technologies.
Other Comments:
Trojan Technologies have supplied the most UV systems for wastewater disinfection applications in the world; state-of-the-art technical support centre available for customers; considerable experience; R&D, state- of-the-art lamp and ballast laboratory, microbiology laboratories; individualized project management
Info on Equipment (brochures, etc.):
Info – brochures, system specifications; awaiting list of installations at WWTPs and details
Technical and/or Research Papers:
Numerous technical papers. It is also important to note that several Trojan scientists sit as active particpants on advisory boards for organizations such as the USEPA, NWRI, WEF, AWWRF.

Windsor UV Feasibility and Guidance Manual Project Telephone Interview Record

GENERAL			
Manufacturer	Trojan Technologies Inc.	System	UV3000
Years in business	25 years	Suppliers	H2Flow Equipment Inc. (in Ontario)
UV EQUIPMENT			
Recommended UV dose	> 32 mJ/cm^2 (for typical secondary effluents, please note that this can vary based on effluent parameters such as UVT and solids as well as the upstreat treatment process)	Flow rate limitation	Small-to-medium sized applications
Lamps per reactor	2 – 16 per module	Type of lamp	Low pressure / low intensity
Configuration	Lamps horizontal and parallel to flow	Mounting	Modules installed in open channels as banks
Power consumption	87.5 W per lamp nominal (including ballast)	Size of standard reactor	Typically 2 banks in series; channels in parallel
Lamp operating life	13,000 hours (guaranteed to 8,760 hrs)	Plant size application	0-10 (please note that this is the typical flow range. Trojan does have UV3000 systems in use for up to 115 MGD US)
Germicidal UV production	32 watts	Ballast location	Enclosure in module frame; convection air-cooled
Special Features	Energy efficient electronic ballast (air cooled by convection)		
MONITORING EQUIPMENT			
Online monitoring available	UV intensity, flow rate	Recommended monitoring	Site specific
Available controls	Remote control, flow pacing; gate control for multi channel operations; numerous alarms; Optional advanced control system available (PLC host)	Variable output capability	No; on/off control of UV banks only
CLEANING MECHANISM			
Automatic or manual	Manual	Frequency	Site specific (depending on process, can be in excess of three to four months); scheduled manual cleaning
If automatic, type	Not applicable	Mechanical or chemical	Not applicable; cleaning in external tank
REFERENCES			
Validation/certification protocols	Independant third party bioassay validation (performed by Dillon Consulting Limited)	Number of installations and sizes	>2000
Operating years at sites	20 with this type of technology	Similar sites	Varying degrees of system size and automation
COSTS			
Capital cost for various sizes	The capital costs can vary from tens of thousands	Operating and maintenance costs	Again, the variations in costs are almost limitless

	of dollars to millions of dollars depending on the flow rates, effluent quality, upstream process and other desired options.		based on system size, effluent quality, disinfection season, power costs, etc.
Chemicals (automatic cleaning)	Not applicable	Lamp replacement costs	$50 per lamp (list price)
MISC.			
Mercury content of system	30 mg	Lamp operating temperature	40°C
Maximum ambient humidity	No limitation, the system is designed to be installed outdoors in a wastewater plant.	Fouling rate	Site specific based on upstream process, solids, etc.
Head loss per bank	2" over the top lamp on the upstream bank.	Required contact time	2 seconds to 15 seconds based on effluent parameters and target dose
Means of level control	Automatic level control (ALC or weir); site specific design	Pretreatment requirements	Not necessary for secondary treated effluent
Serviceability	Designed to be low maintenance system. No special tools required. Lamps can be changed without tools. Modules are light weight and can be easily handled by one operator.	Availability of pilot plant	Trojan has two UV3000 pilot plants that are available on a fist come basis and are rented out at $2,250 per month for the equipment only (not including shipping, or any applicable taxes)

GENERAL			
Manufacturer	Trojan Technologies Inc.	System	System UV3000*Plus*
Years in business	25 years	Suppliers	H2Flow Equipment Inc. (in Ontario)
UV EQUIPMENT			
Recommended UV dose	> 24 mJ/cm^2 with on line cleaning system or > 32 mJ/cm^2 without on line cleaning system (for typical secondary effluents, please note that this can vary based on effluent parameters such as UVT and solids as well as the upstream treatment process)	Flow rate limitation	Small-to-medium sized applications
Lamps per reactor	2 – 8 per module	Type of lamp	Low pressure / high intensity
Configuration	Lamps horizontal and parallel to flow	Mounting	Lamp modules on support racks in open channel(s)
Power consumption	250 W per lamp nominal	Size of standard reactor	Typically 2 banks in series; channels in parallel
Lamp operating life	12,000 hours (guaranteed to 8,760 hrs)	Plant size application	Up to about 57 MLD (15 USmgd); (please note that this is the typical flow range. Trojan does have UV3000Plus systems in use for up to 70 MGD US)
Germicidal UV production	100 watts	Ballast location	Enclosure in module frame; convection air cooled
Special Features	Energy efficient electronic ballast; variable output lamps (preheated); flow/dose pacing; optional automatic cleaning system		
MONITORING EQUIPMENT			
Online monitoring available	UV intensity, flow rate	Recommended monitoring	Site specific; grab sample UVT monitoring utilizing a bench top photometer (an optional on-line UVT is available and may be recommended if the UVT of the effluent has wide daily fluctuations. It is important to note that an on-line UVT is a laboratory device and requires maintenance as such).
Available controls	Microprocessor-based control system or optional advanced PLC; flow/dose pacing, remote control, gate control for multi channel operations; numerous alarms	Variable output capability	Automatic and continuous; can turn banks on and off as well as vary to 60-100% power range for each bank.
CLEANING MECHANISM			
Automatic or manual	Automatic (optional)	Frequency	Fully operator configurable at the control panel from once every hour to once every 999 hours.
If automatic, type	Controls based on timer or UV intensity;	Mechanical or chemical	*In-situ* mechanical/chemical cleaning system

	magnetically coupled drive		(patented)
REFERENCES			
Validation/certification protocols	Independant third party bioassay validation (performed by Dillon Consulting Limited)	Number of installations and sizes	>100; typically >19 MLD (5+ USmgd)
Operating years at sites	>20; (> 3 with System UV3000*Plus*)	Similar sites	Varying degrees of system automation
COSTS			
Capital cost for various sizes	The capital costs can vary from tens of thousands of dollars to millions of dollars depending on the flow rates, effluent quality, upstream process and other desired options.	Operating and maintenance costs	Again, the variations in costs are almost limitless based on system size, effluent quality, disinfection season, power costs, etc.
Chemicals (automatic cleaning)	$41 per gallon (subject to change). The cleaning system requires 40 ml of cleaning solution per lamp.	Lamp replacement costs	$215 per lamp (list price) subject to change.
MISC.			
Mercury content of system	50 mg	Lamp operating temperature	100°C
Maximum ambient humidity	No limitation, the system is designed to be installed outdoors in a wastewater plant.	Fouling rate	Site specific; eliminated with automatic mechanical/chemical cleaning
Head loss per bank	2.25" over the top lamp on the upstream bank.	Required contact time	2 seconds to 15 seconds based on effluent parameters and target dose
Means of level control	Automatic level control; site specific design	Pretreatment requirements	Not necessary for secondary treated effluent
Serviceability	Reduced maintenance for fully automated systems. Designed to be low maintenance system. No special tools required. Lamps can be changed without tools.	Availability of pilot plant	Trojan has two UV3000Plus pilot plants that are available on a fist come basis and are rented out at $2,250 per month for the equipment only (not including shipping, or any applicable taxes)

GENERAL			
Manufacturer	Trojan Technologies Inc.	System	System UV4000
Years in business	25 years	Suppliers	H2Flow Equipment Inc. (in Ontario)
UV EQUIPMENT			
Recommended UV dose	> 24 mJ/cm^2 (for typical secondary effluents, please note that this can vary based on efluent parameters such as UVT and solids as well as the upstreat treatment process)	Flow rate limitation	Medium-to-very large flow system; modular
Lamps per reactor	4 to 24 lamps per module (lamps in increments of 2)	Type of lamp	Medium pressure / high intensity
Configuration	Lamps horizontal and parallel to flow	Mounting	Installed into open channel; 2 banks in series
Power consumption	2.8 kW per lamp (including ballast)	Size of standard reactor	2 banks in series; site specific
Lamp operating life	8,000 hours (guaranteed to 5,000 hrs on a prorated basis)	Plant size application	Medium-to-very large flow treatment systems
Germicidal UV production	400 watts	Ballast location	Enclosed in module frame; cooled by glycol recirc.
Special Features	Energy efficient electronic ballast; variable output lamps; flow/dose pacing; automatic cleaning system; Module Removal Mechanism		
MONITORING EQUIPMENT			
Online monitoring available	UV intensity, flow rate, UVT	Recommended monitoring	Site specific; grab sample UVT monitoring utilizing a bench top photometer (an optional on-line UVT is available and may be recommended if the UVT of the effluent has wide daily fluctuations. It is important to note that an on-line UVT is a laboratory device and requires maintenance as such).
Available controls	Microprocessor-based control system or optional advanced PLC; dose pacing, remote control, gate control for multi channel operations; numerous alarms	Variable output capability	Automatic and continuous; can turn banks on and off as well as vary between 30-100% power range for each bank.
CLEANING MECHANISM			
Automatic or manual	Automatic	Frequency	Fully operator configurable at the control panel from once every hour to once every 999 hours.
If automatic, type	Controls based on timer or UV intensity; magnetically coupled drive	Mechanical or chemical	*In-situ* mechanical/chemical cleaning system (patented).

REFERENCES			
Validation/certification protocols	Numerous pilot studies	Number of installations and sizes	>250; typically >26 MLD (7+ USmgd)
Operating years at sites	>20 years; (>7 years with System UV4000)	Similar sites	Similar; number of modules and banks in series vary
COSTS			
Capital cost for various sizes	The capital costs can vary from tens of thousands of dollars to millions of dollars depending on the flow rates, effluent quality, upstream process and other desired options.	Operating and maintenance costs	Again, the variations in costs are almost limitless based on system size, effluent quality, disinfection season, power costs, etc.
Chemicals (automatic cleaning)	$41 per gallon (subject to change). The cleaning system requires 200 ml of cleaning solution per lamp.	Lamp replacement costs	$250 per lamp (list price) subject to change.
MISC.			
Mercury content of system	150 mg	Lamp operating temperature	600-800°C
Maximum ambient humidity	No limitation, the system is designed to be installed outdoors in a wastewater plant.	Fouling rate	Site specific; minimized by automatic self-cleaning
Head loss per bank	The UV4000 is designed to fix the water layer around each lamp through the reaction chamber. Depending on flow, the head loss across the unit can vary from several inches to a few feet.	Required contact time	Typically less than 1 second based on effluent parameters and target dose
Means of level control	Automatic level control; site specific design	Pretreatment requirements	Not necessary for secondary treated effluent
Serviceability	Designed to be low maintenance system. Any special tools required supplied with system.	Availability of pilot plant	Trojan has two UV4000 pilot plants that are available on a fist come basis and are rented out at $3,750 per month for the equipment only (not including shipping, or any applicable taxes)

Appendix B
Site Visit Summaries and Report

INFORMATION SHEET	
GENERAL	
Location:	Sarnia WWTP
Date:	February 14, 2002
Address:	Sarnia WWTP St. Andrew St. Sarnia
Contact:	Mr. Terry Allen
Phone/Fax/email:	519-344-8507/519-344-8529 tallen@mnsi.net
FACILITY	
No. of Parallel Plants:	Primary clarifiers, activated sludge
Treatment Processes & Type:	
Flows (current/design/peak):	38.7 MLD/avg, 182 MLD/peak
Typical Influent (mg/L):	
Typical Effluent (mg/L):	
W/W Temperature (°C):	
Effluent Limits:	0.8 TP, 1.5 to 3 NH3-N, 200 organisms/100 mls
UV PROCESS	
Manufacturer:	Trojan Technologies/ Trojan 4000
Type (LP/MP/LI/HI):	Medium Pressure/ High Intensity
No. of lamps:	112 (7 modules/8 lamps/module)
No. of Banks	2
No. of Channels:	1
Lamp rating (W):	
Orientation (horiz or vert):	Horizontal
Date Installed:	Spring 2001
Ballast #/location:	Top of module/1 ballast/lamp/8 ballasts/module
Cleaning (manual/auto):	Auto
Cleaning Frequency:	Cleaning every ½ hour
PARTICULARS	
Controls (system and instr):	Flow paced, hydraulic driven wiper/ time based/ Intensity Sensor per bank
Control Parameters	
Power Usage:	Flows
Design UV Dose:	

INFORMATION SHEET	
UV PERFORMANCE	
Influent Bacteria (#/100 mls):	
Effluent Bacteria (#/100 mls):	200 generally between 50 to 75 at avg, 1000 to 3000 at 155 and 182 MLD
Transmittance (%):	
DESIGN CRITERIA	
Effluent SS (mg/L):	Design Avg 10/30 mg/L SS/BOD$_5$
Transmittance:	60% at avg, 50% at peak
Operation:	
Guarantees (lamps/ballasts etc)	18 months (maintenance package)/5000 hr on lamps
UV SYSTEM COSTS	
Capital Cost:	\$694,700 UV equipment excluding taxes
O&M Costs	Superintendent has \$35,000/year in budget for system
Lamps	
Electrical	Spec calls for 7500 hours on lamps
Cleaning	
Maintenance	
Replacement parts	
Replacement Costs	
Lamps	\$200 for lamps and for sleeves excluding taxes
Ballasts	Generally about \$200/ indicated they pay \$125/lamp
Wipers	
OTHER INFORMATION Serial #305 480V/202 kW/60 Hz/3 ph one of two	Additional info: Lamps at 30% during visit for both modules, not sure why one module wasn't running Lamps replaced after 5000 hrs (generally 5800 hr/ still not failed) Bypass + eff treated during high flows Problem with controller enclosure, can't read screen Hydraulic oil stored at site/ line break noted
INFORMATION COLLECTED	Costs from EarthTech Pre-selection spec (EarthTech)

INFORMATION SHEET	
Photos taken (no. and description)	
A. Main building	Main building/plant sign
B. Overview	Overview of UV system looking downstream
C. Top of module	Looking through module on top
D. MCC panel	Main control (H-O-A)
E. Intensity instr	Intensity instrument connection
F. Control panel	Outside control panel
G. Control screen	Inside control panel/controller screen
H. Quartz sleeve	New quartz sleeve in box
I. Used lamp	Used lamp with >5000 hrs
J. Channel grates	Removal of grate to access lamps
K. Removing mod1	Pulling module from channel
L. Removing mod2	Pulling module from channel
M. Lamps out	Lamps in full out position
N. Wiper	Wiper in operation
O. Cooling pumps	Pumps for ballast cooling system
P. Wiper hydr pump	Pump for wiper
Q. Ballast	Ballast (spare)
R. Overview mod out	Overview of system

General Questions

As part of "Other Information" some potential questions are :

Were plant and UV system operations considered normal at the time of the tour?
Plant was operating normally, operation of UV questioned ie 2 banks at 30%

What have been the main UV system design limitations/difficulties?
Some problems with hydraulic lines, and ability to read screen

What have been the main UV system operational limitations/difficulties?
Access to modules difficult with grates, no enclosure makes work on system in cold weather a problem

How have these been resolved (e.g., design and/or operational modifications)?
Plant intents to add a structure or roof over system

General recommendations/advice?
Provide enclosure for system

WATER POLLUTION CONTROL CENTRE

Photo A

Photo B

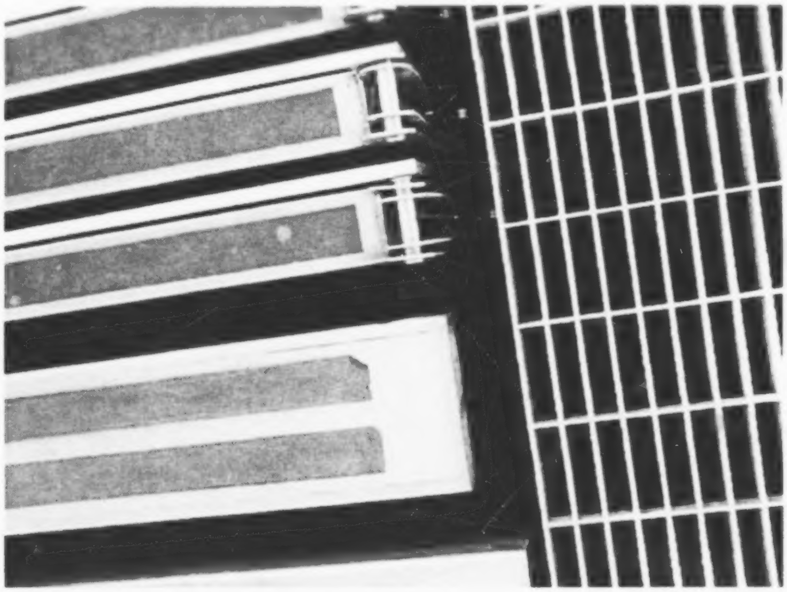


Photo C

Photo D

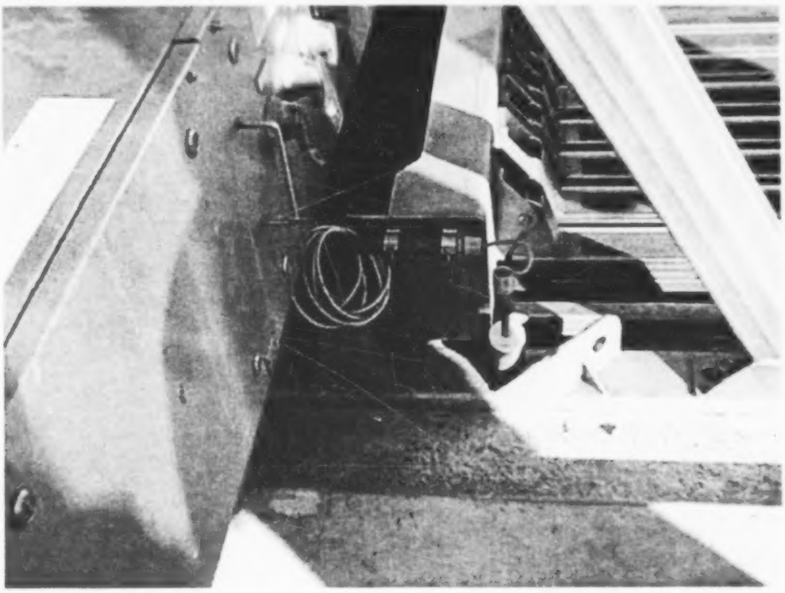


Photo E

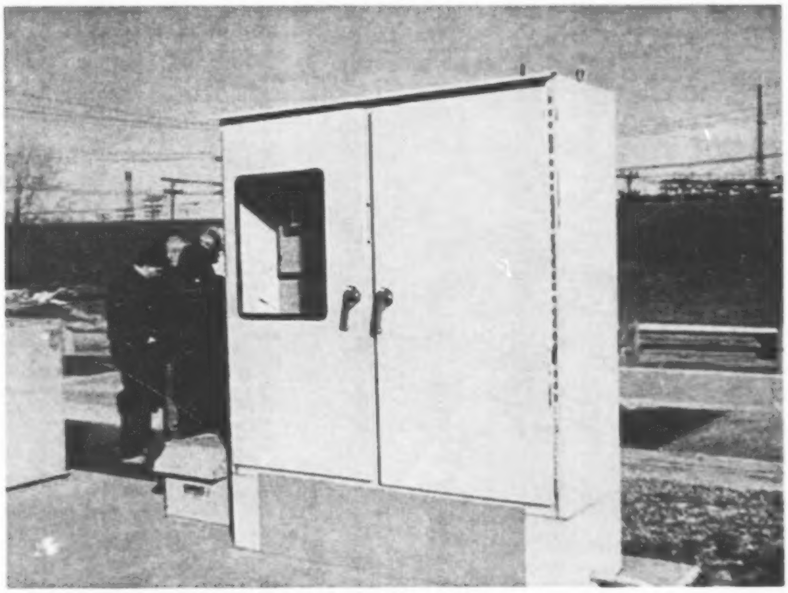


Photo F

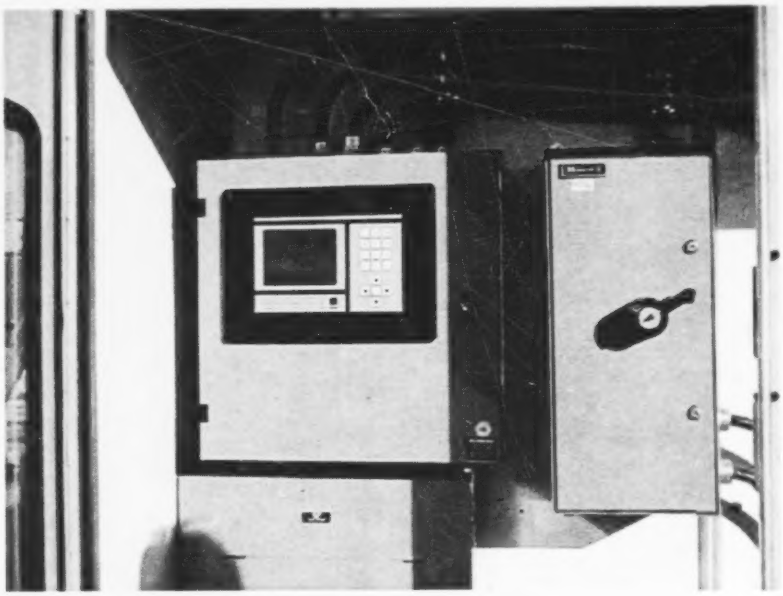


Photo G

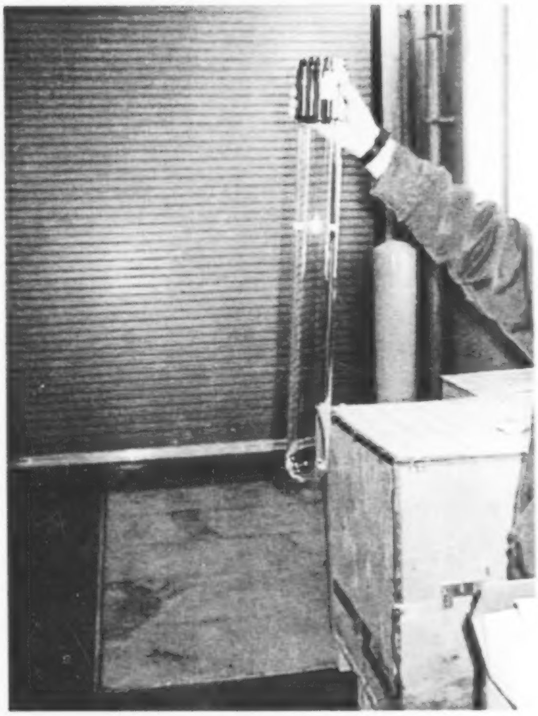


Photo H

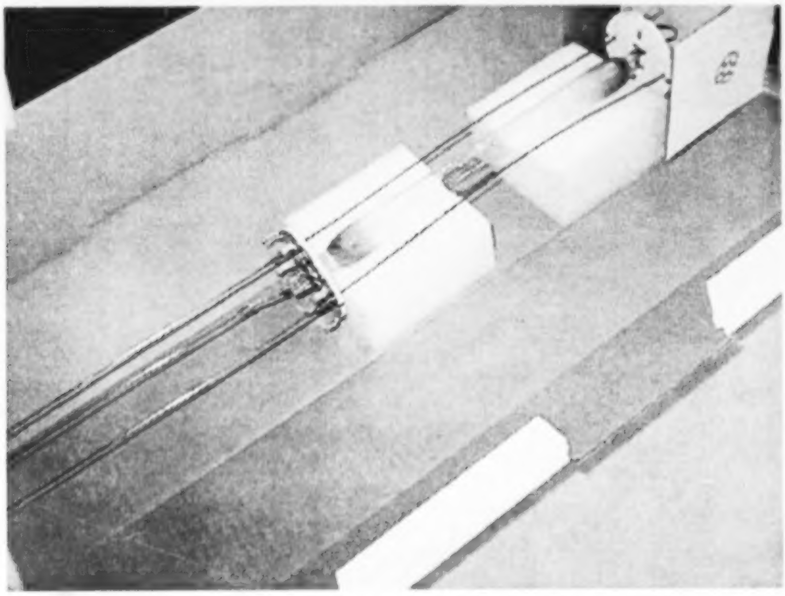


Photo I

Photo J

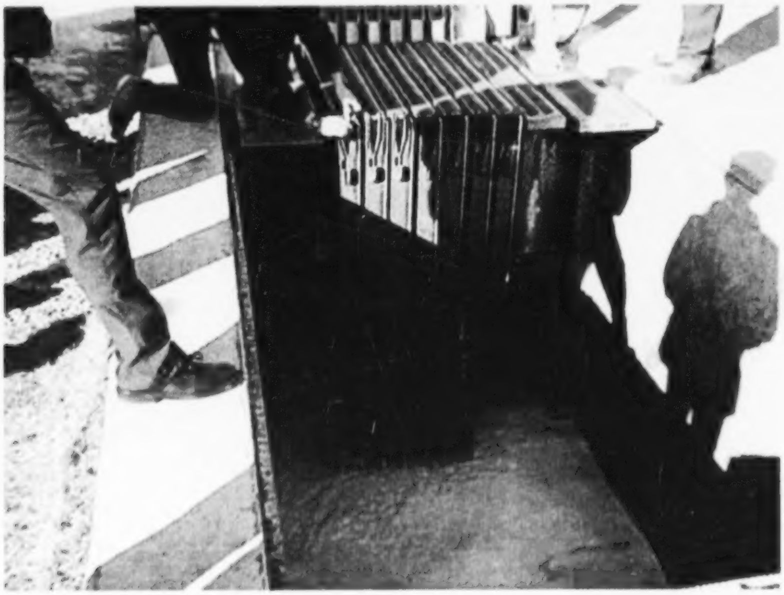


Photo K

Photo L

Photo M

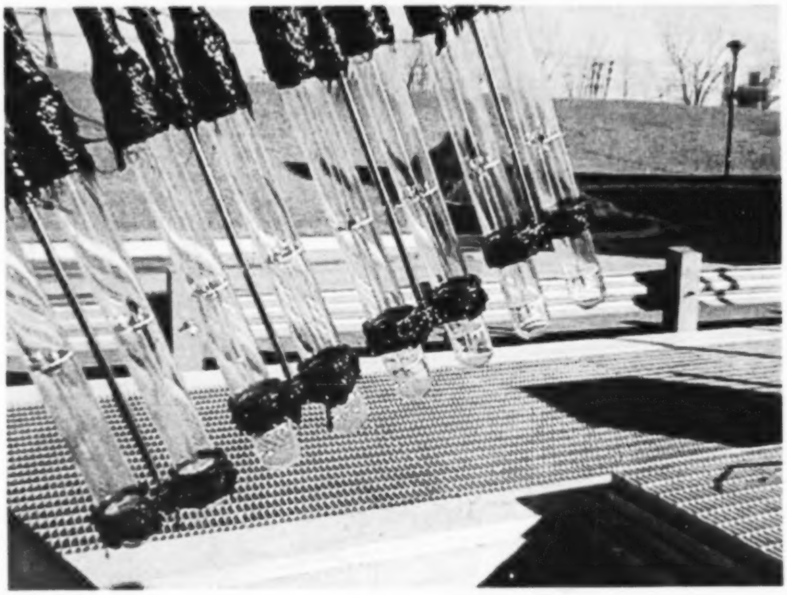


Photo N

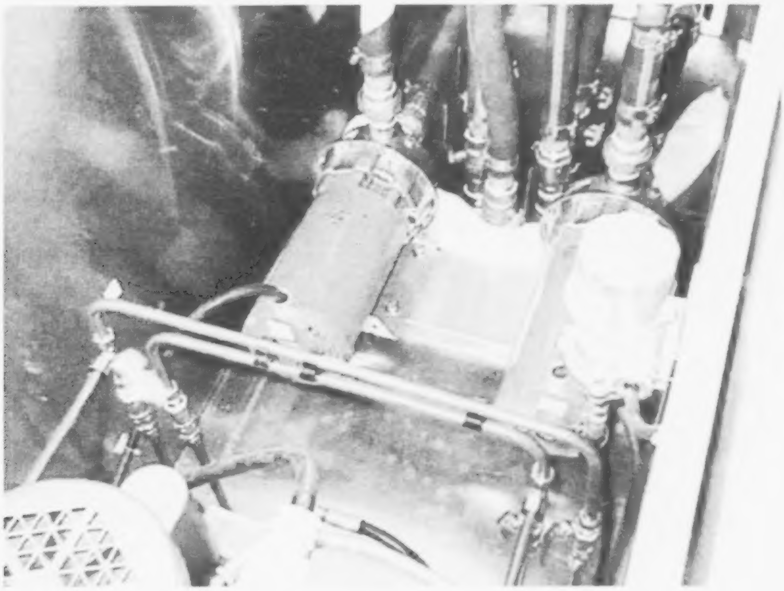


Photo O

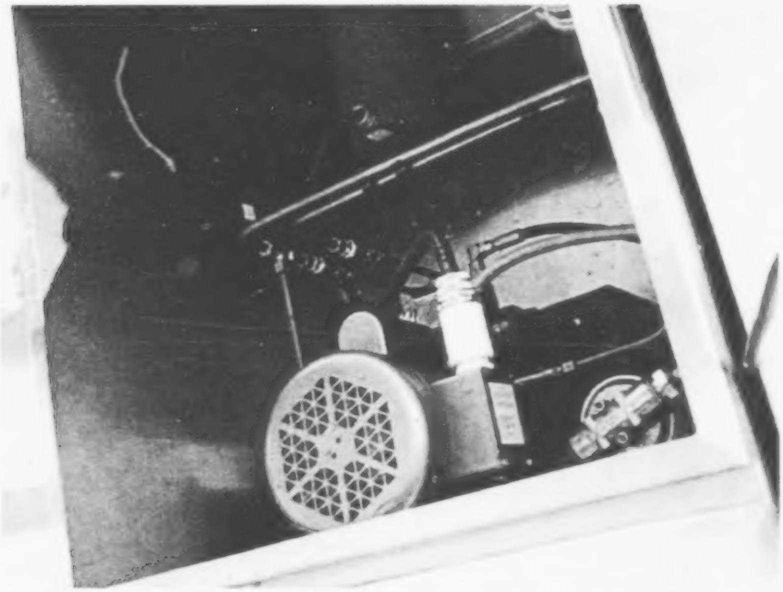


Photo P

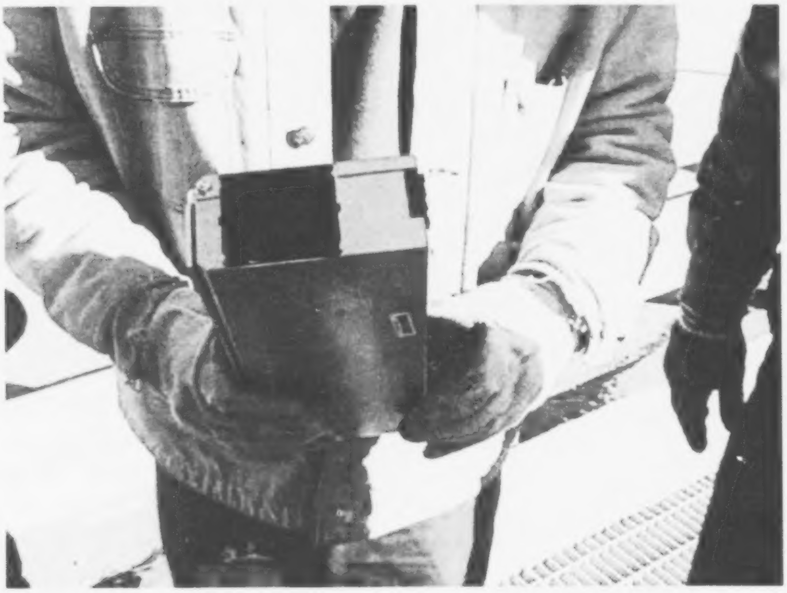


Photo Q

Photo R

INFORMATION SHEET	
GENERAL	
Location:	Oxford PCP
Date:	February 14, 2002
Address:	Oxford St. West London
Contact:	Mr. Brian Bellamy (Toured by Operations Todd/Tim)
Phone/Fax/email:	519-661-0350
FACILITY	
No. of Parallel Plants:	Primary clarifiers and activated sludge, 2 plants
Treatment Processes & Type:	ASP
Flows (current/design/peak):	10 MLD average (2.2 mgd), current 1-1.5 mgd (4.5-6.8 MLD)
Typical Influent (mg/L):	230 mg/L
Typical Effluent (mg/L):	4 mg/L
W/W Temperature (°C):	16-19 °C
Effluent Limits:	5 (SS), 5 (BOD), 0.5 (PO_4), 200 (FC) [objective] Nitrification 2 obj/ 3 limit year round
UV PROCESS	
Manufacturer:	Trojan Technologies/ Trojan 3000+
Type (LP/MP/LI/HI):	Low Pressure/ High Intensity
No. of lamps:	84
No. of Banks	7 modules per bank, 6 lamps per module
No. of Channels:	2
Lamp rating (W):	250
Orientation (horiz or vert):	Horizontal
Date Installed:	Feb 2000
Ballast #/location:	Module handle 1 ballast per 2 lamps
Cleaning (manual/auto):	Automatic
Cleaning Frequency:	Testing facility currently running every 15 min for testing

INFORMATION SHEET

PARTICULARS	
Controls (system and instr):	Intensity sensor per bank
Control Parameters Power Usage:	Flow, no transmittance, currently testing at constant 60 and 100 % power – non-disinfection season testing by Trojan
Design UV Dose:	Design 7.96 – 3.26 at 60% output
UV PERFORMANCE	
Influent Bacteria (#/100 mls):	
Effluent Bacteria (#/100 mls):	200 *E.coli.*
Transmittance (%):	55 set in controller
DESIGN CRITERIA	
Effluent SS (mg/L):	
Transmittance:	65%
Operation:	Seasonal when not testing by Trojan
Guarantees (lamps/ballasts etc)	Site testing lamp hours, currently >9000 hrs
UV SYSTEM COSTS	
Capital Cost:	
O&M Costs	
Lamps Electrical Cleaning Maintenance Replacement parts	As test site, plant is paying electricity, Trojan does maintenance
Replacement Costs	
Lamps Ballasts Wipers	
OTHER INFORMATION Serial # HSC0000110 120 V/30 A/ 60 Hz/ Phase 1	Site is test facility, existing Trojan 2000 replaced with 3000[1], currently testing controller settings 7.96 and 3.26 intensity (lower for 60% power) 3 and 6 lamps out for each module (part of test) Previous system (2000) had 8 lamps/mod, 10 mod, 2 channel and 2 banks (total 320 lamps)

INFORMATION SHEET	
	Quartz sleeves longer for 3000', 64" for 2000, +12" for 3000', allows for area for wiper Comparison of 3000' with 84 lamps, vs 2000 with 320, 3.8 reduction – which is higher than lamp rating difference of 2.8 (250/87.5 W)
INFORMATION COLLECTED	Sheet filled out by staff
Photos taken (no. and description)	
A. entrance	Entrance to plant/sign
B. overview	Overview of system, upstream facing down
C. controller screen	Interface panel/screen
D. hydraulic	Hydraulic lines for cleaning system/wiper
E. top view	View from top looking upstream/level baffles
F. screen	Control screen, showing bank lamp status
G. controller panel	Outside of controller panel
H. old system	Trojan 2000 system in workshop (replaced system)

General Questions

As part of "Other Information" some potential questions are :

Were plant and UV system operations considered normal at the time of the tour?
Testing ongoing, seasonal disinfection, otherwise normal

What have been the main UV system design limitations/difficulties?
New system reduced lamps, maintenance implication no known since maintenance by Trojan

What have been the main UV system operational limitations/difficulties?
None indicated

How have these been resolved (e.g., design and/or operational modifications)?

General recommendations/advice?
Cover for control panel would be helpful for shelter and light shading

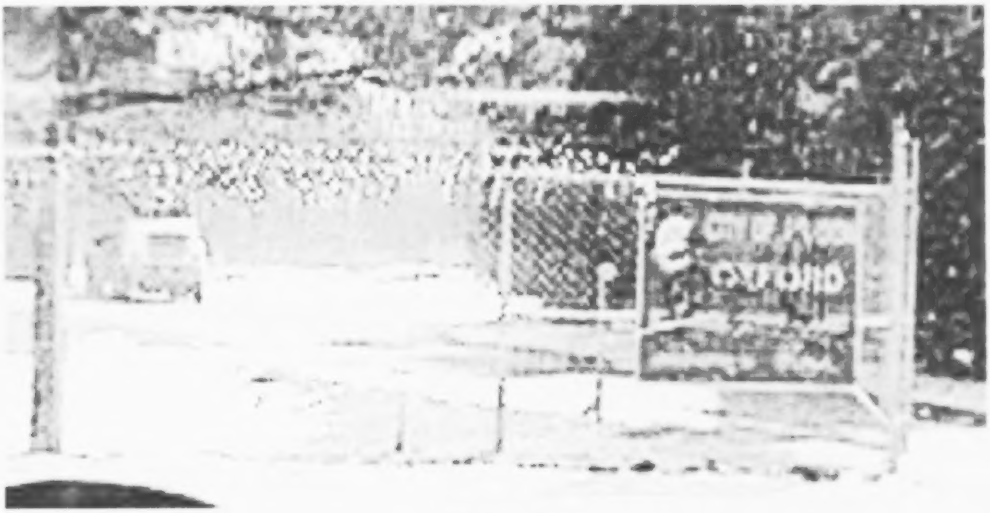


Photo A

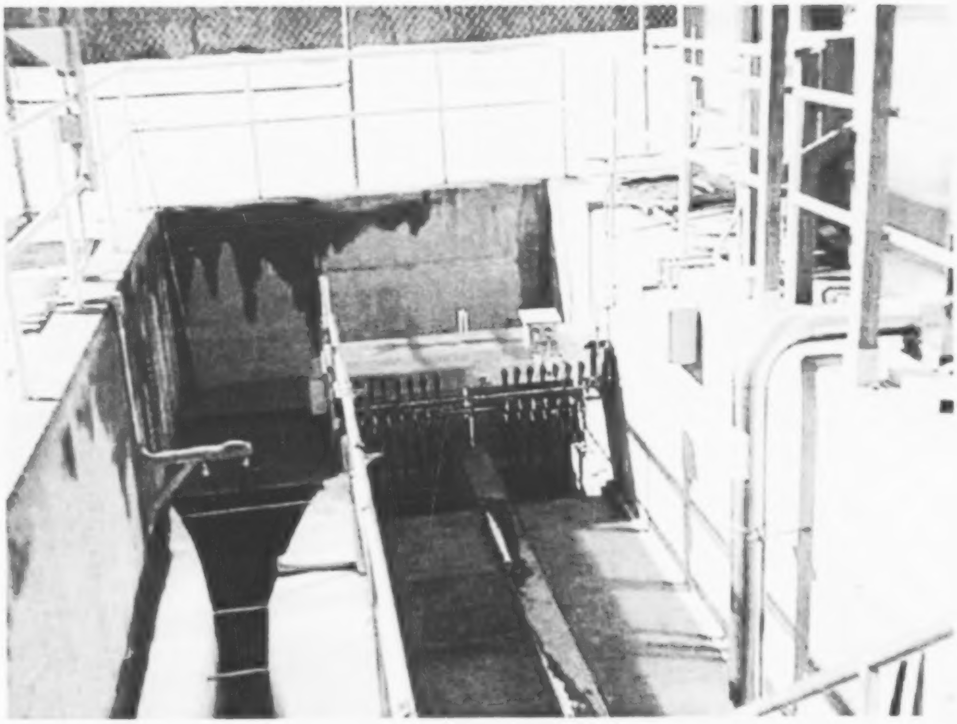


Photo B

TESTING IN PROGRESS
DO NOT CHANGE ANY SYSTEM SETTINGS
THE FOLLOWING SYSTEM SETTINGS
SERVICE CONTROL CENTER
-BANK 1A @ 100%
-BANK 2A @ 60%
-WIPER FREQUENCY @15 MINUTES
FOR FURTHER INFORMATION

Photo C

Photo D

Photo E

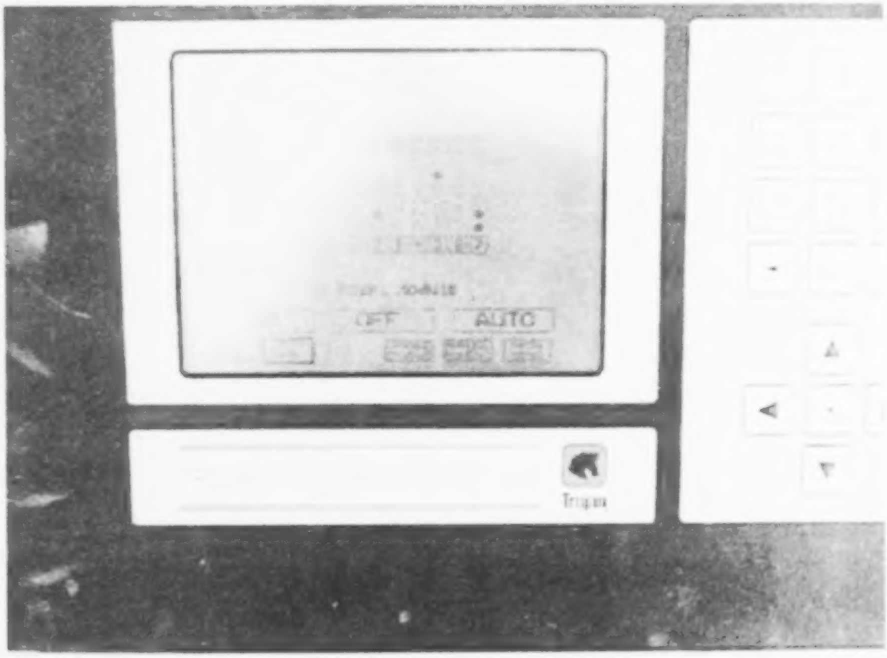


Photo F

Photo G

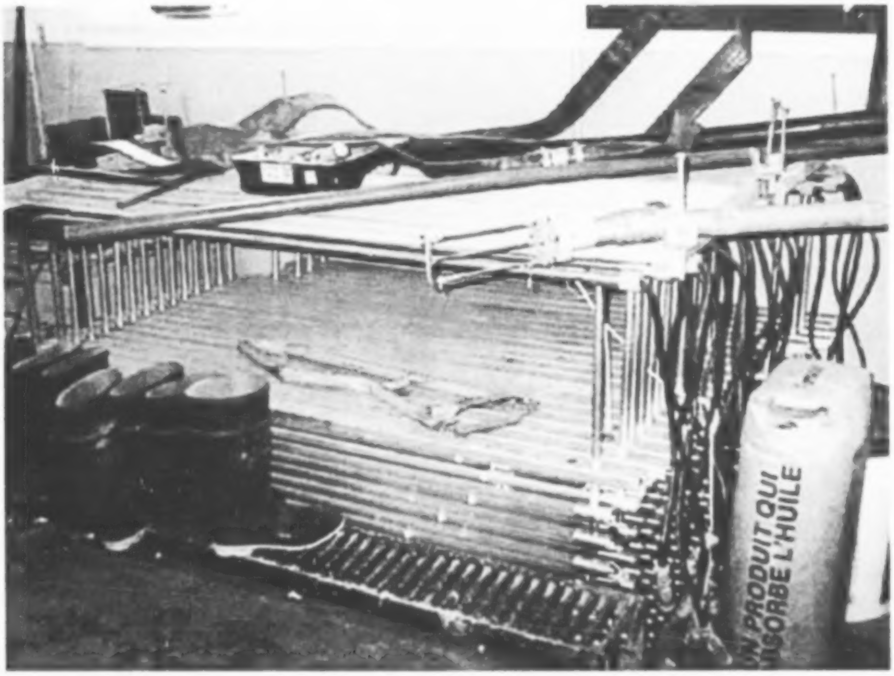

UN PRODUIT QUI
ABSORBE L'HUILE

Photo H

Notes from tour of Trojan Technologies
February 14, 2002

Committee for the UV Windsor Guidance Manual and Feasibility Study visited the Trojan facilities on Gore St. in London to review UV technology and discuss issues. Some main point raised/discussed included:

- Trojan does final assembly and testing at site. Most parts manufactured or fabricated by others
- Wiper systems can be expensive, for larger plants (greater than 40 MLD), the wiper system can be 33% of the capital cost for the system. The Trojan 3000^{+} can be specified without the wiper system and this system can be "easily" retrofitted in at a later date.
- Lamp costs, approx $40 for LI/LP and $200 HI/LP, MP/HI similar to HI/LP
- Sizing/picking system often depends on size, "rule of thumb" less than 15 MLD LP/LI, greater than15 MLD and less than 40 MLD LP/HI (3000+), greater than 45 MLD Trojan 4000 (MP/HI).
- Basically, 16 LP/LI (3000) = 8 LP/HI (3000+) = 1 MP/HI (4000)
- Trojan 3000+ modules are more stream lined than 3000 units, holder is streamlined (forms a V on upstream side), holders are also streamlined (arrowhead design)
- Quartz sleeve is about 300 mm (1 foot) longer with 3000+ than 3000 so the wiper can be parked off the lamp
- Cleaning solution for 3000+ unit is connected between each lamp for each module with a viewing reservoir at top of the top lamp
- Trojan 4000 (MP/HI) can be scaled to 30% of max output
- Testing facilities visited for systems, including testing (3000 and 3000+) air tested, (4000) tested in channel due to heat (i.e. in water).
- Systems can be integrated into plant PLCs and SCADA, Allen Bradley is a standard
- Trojan 4000 design generally 4 to 8 lamps per module, 3 to 40 modules wide
- Trojan uses intensity sensor for monitoring only, sensor is point sensor and quality of sensor would be problem for use in a control strategy (Response to question as to why intensity sensor not used to control lamp output)
- Recycle plan available if lamps purchased from Trojan (often guaranteed price with contract). 4000 lamps must be purchased through Trojan, 3000 and 3000+ could be purchased from others
- Cleaning system for Trojan 4000 includes 4 lamps together

- New staggered design (as seen at Preston, see picture attached) allows for less modules and wider ballast area, allowing ballasts to be mounted horizontally for better air circulation
- Trojan 4000 is designed for 2.8 K per lamp
- Hydraulic design is 10 ft/s (3 m/s) for Trojan 4000, and 1-1.5 ft/s (0.3 to 0.45 m/s) for the Trojan 3000+
- Cooling fluid for Trojan 4000 (i.e. ballast cooling) is circulated into the top of channel insert into a closed area to be cooled by the wastewater
- Inspected clean water UV units including 12 inch (3.3 mgd) with 2 to 4 lamps (2.8KW MP/HI lamps) and 24 inch (20 mgd) with 10KW MP/HI lamps. Clean water systems use food grade cleaner in wiper unit
- Lamp life discussed results at Oxford could indicate greater lamp life, somewhere between 8000 and 12000 hrs, guarantee expected to change shortly

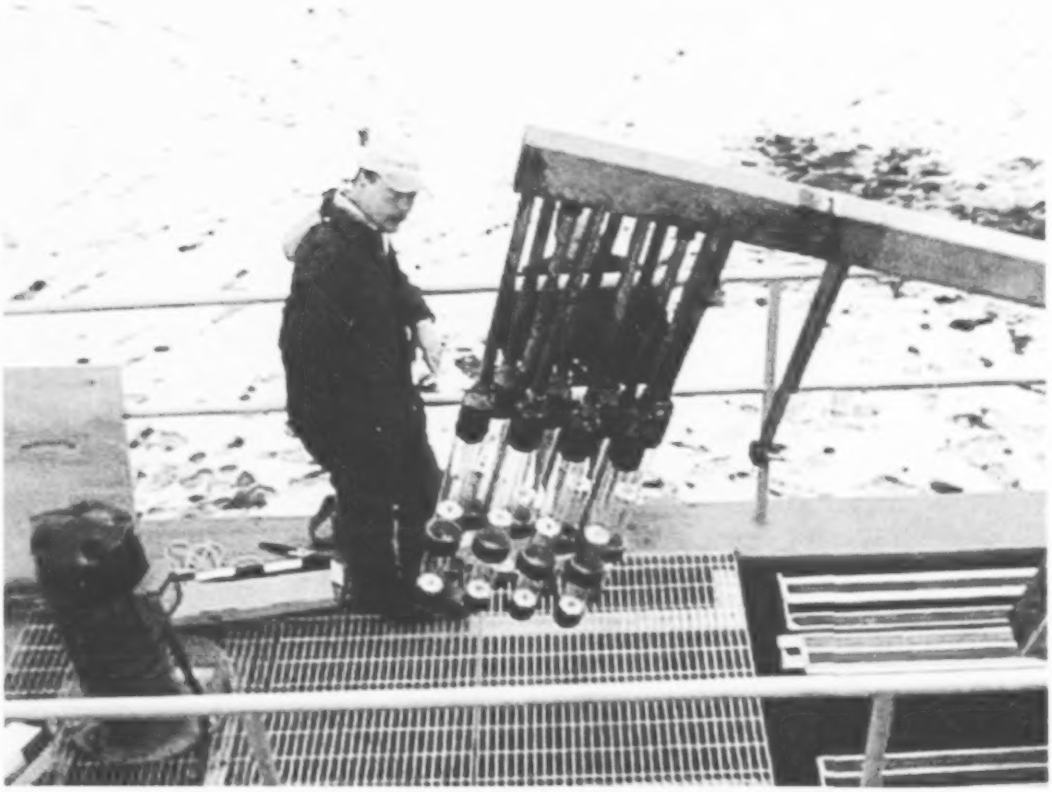


Photo 1 – Trojan 4000 with new Staggered Design (Preston WWTP)

INFORMATION SHEET

GENERAL	
Location:	Grandville WWTP, Grandville MI
Date:	February 22, 2002 (to be confirmed)
Address:	4747 Jenison Rd. Grandville, MI 49418
Contact:	Mr. Richard Meyers
Phone/Fax/email:	616-457-0720/616-457-0315 meyrich@iserv.net
FACILITY	
No. of Parallel Plants:	Activated Sludge
Treatment Processes & Type:	
Flows (current/design/peak):	4.4 /10 mgd, (16.5/38 MLD) avg and peak design
Typical Influent (mg/L):	219 (SS) 220 (BOD)
Typical Effluent (mg/L):	11 (SS) 6 (CBOD)
W/W Temperature (°C):	40-76 °F (4 – 24 °C)
Effluent Limits:	30 (SS), 25 (CBOD), 15 (NH3), 1.0 (TP), 200 FC, 400 FC 7-day max
UV PROCESS	
Manufacturer:	Wedeco
Type (LP/MP/LI/HI):	Low Pressure/ High Intensity
No. of lamps:	96 (48 per bank, 4 modules 6x2 lamps per module)
No. of Banks	2
No. of Channels:	1
Lamp rating (W):	125 W at germicidal – 330 W power input/lamp
Orientation (horiz or vert):	Horizontal
Date Installed:	1-9-02 (Jan 2002)
Ballast #/location:	48 Panel Mounted
Cleaning (manual/auto):	Auto
Cleaning Frequency:	20 min
PARTICULARS	
Controls (system and instr):	SLC/1746 system
Control Parameters	Effluent level control, UV trans, Dose, Intensity & flow used for UV control
Power Usage:	Max 32 kW
Design UV Dose:	37,000 uW-s/cm^2

INFORMATION SHEET	
UV PERFORMANCE Influent Bacteria (#/100 mls): Effluent Bacteria (#/100 mls): Transmittance (%):	66000 39 69
DESIGN CRITERIA Effluent SS (mg/L): Transmittance: Operation: Guarantees (lamps/ballasts etc)	25 65 continuous 12000 lamps-hours , Ballasts one year
UV SYSTEM COSTS Capital Cost:	$277,000 total project/ $172,816 for UV equipment only
O&M Costs Lamps Electrical Cleaning Maintenance Replacement parts	
Replacement Costs Lamps Ballasts Wipers	Inventory not maintained, concern over shelf life
OTHER INFORMATION	See attached notes Wedeco Contact: Ron Crawlet, 212 Ideal Way, Poultney, Vermont)5764 (802)-287-4488/(802)-287-4486 (fax)
INFORMATION COLLECTED	Cost breakdown for project Additional notes attached
Photos taken (no. and description) Photo A – Plant Sign Photo B – Plant Aerial Photo C – Module Connections Photo D – Ballasts	

INFORMATION SHEET	
Photo E - PLC Controller Photo F – Lamps in Operation Photo G – Overview of UV Photo H – Close-up of UV Module	

General Questions

As part of "Other Information" some potential questions are :

Were plant and UV system operations considered normal at the time of the tour?
Yes, normal operation 2 banks operating at minimum

What have been the main UV system design limitations/difficulties?
Early lamp replacement for 2 lamps, otherwise no operational problems but only operating for 44 days

What have been the main UV system operational limitations/difficulties?
None

How have these been resolved (e.g., design and/or operational modifications)?
Too early to tell

General recommendations/advice?
Plant evaluating covering units

GRANDVILLE
WASTE WATER
PLANT

Photo A – Plant Sign

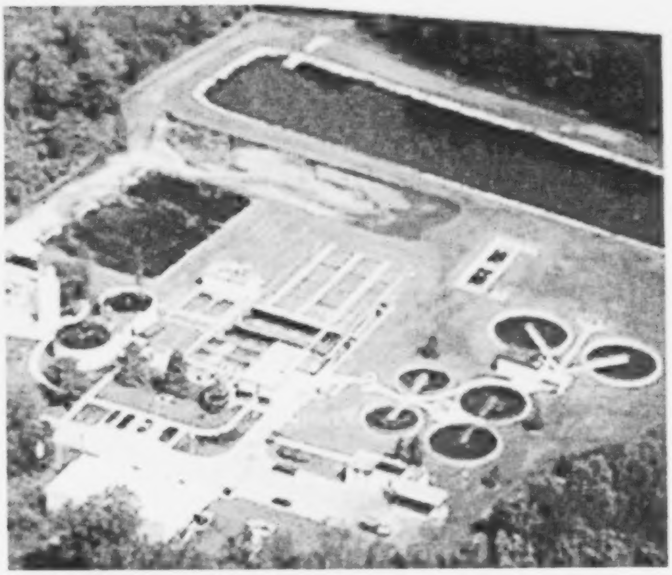


Photo B – Plant Aerial

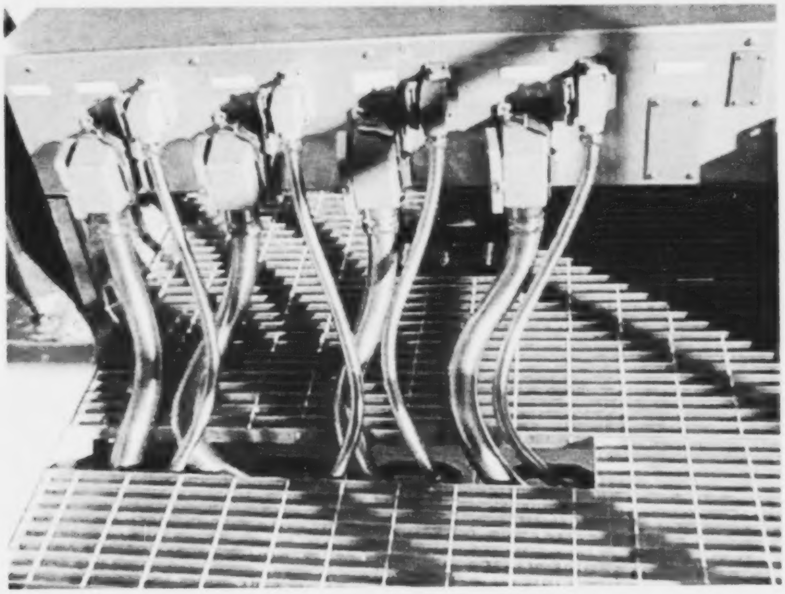


Photo C – Module Connections for Power and Wiper System

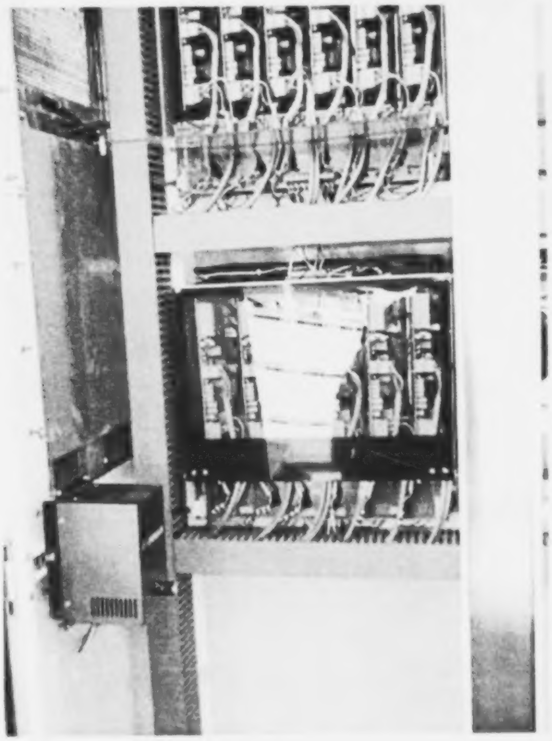


Photo D – Lamp Ballasts (Electronic, 2 lamps per Ballast)

Photo E – PLC Controller

Photo F – Lamps in Operation

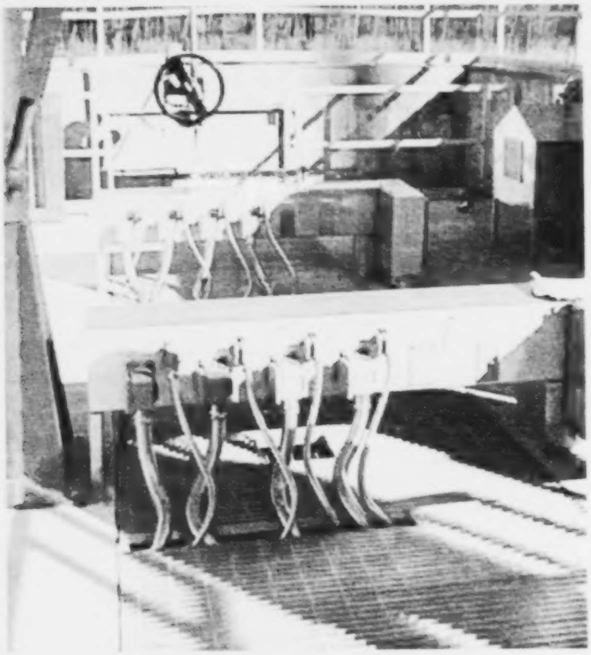


Photo G – Overview of UV System

Photo H – Spare Module Close-up

INFORMATION SHEET

GENERAL	
Location:	Deseronto WWTP
Date:	March 5, 2002
Address:	Bayshore Rd., Deseronto
Contact:	Mr. Dave Johnson, Plant Manager
Phone/Fax/email:	613-396-3435 phone/ 613-396-1517 fax
FACILITY	
No. of Parallel Plants:	
Treatment Processes & Type:	Extended aeration package plant with tertiary system (Actiflo)
Flows (current/design/peak):	1.21 mgd (5.5 MLD) peak flows, summer flows, current flow 0.22 mgd (1 MLD)
Typical Influent (mg/L):	118/126 peak BOD, 170 SS 1-5 BOD (3), 4 SS, 2-7 MPN/100 mL
Typical Effluent (mg/L):	
W/W Temperature (°C):	25,25, 1 BOD/SS/TP, 100 MPN/100 mL
Effluent Limits:	
UV PROCESS	
Manufacturer:	Suntec environmental
Type (LP/MP/LI/HI):	LP/HI
No. of lamps:	32
No. of Banks	2, 2 modules per bank, 8 lamps (2x4) per module
No. of Channels:	1
Lamp rating (W):	200 W (220 Volt)
Orientation (horiz or vert):	Horizontal
Date Installed:	November 2000
Ballast #/location:	32 ballasts, on lamp submerged
Cleaning (manual/auto):	auto
Cleaning Frequency:	4 hr cleaning cycle
PARTICULARS	
Controls (system and instr):	Intensity sensor for each bank, could be flow paced and modulated, current manually modulated, Actiflo system off, 2 banks running during tour
Control Parameters	Flow – not current tied in
Power Usage:	Both banks operating with high intensity of 22.7 mW/cm^2
Design UV Dose:	max 25 mW/cm^2

INFORMATION SHEET	
UV PERFORMANCE Influent Bacteria (#/100 mls): Effluent Bacteria (#/100 mls): Transmittance (%):	None Available
DESIGN CRITERIA Effluent SS (mg/L): Transmittance: Operation: Guarantees (lamps/ballasts etc)	None Available
UV SYSTEM COSTS Capital Cost: O&M Costs Lamps Electrical Cleaning Maintenance Replacement parts Replacement Costs Lamps Ballasts Wipers	None available None available Spare parts evident at plant including, one complete module, lamps and quartz sleeves
OTHER INFORMATION	Other points: Wires for lamps run length of lamp, might be trouble when changing Units are pulled and hosed 1/week Current problem with sand carryover from Actiflo, plant running 2 banks 4 hr cleaning cycle, moved from 6 hr Lamp elapse hours at 6094 hr Output at 100% during tours Weir level varied slightly, top lamps on downstream module cycles from just covered to ¼ lamp exposed
INFORMATION COLLECTED	

INFORMATION SHEET	
Photos taken (no. and description)	
A. UV overview	Overview of UV system looking upstream
B. Closeup lamp	Closeup of lamps while on in channel
C. Effluent weir	Effluent controller weir
D. UV module ballast	Extra module on rack showing ballast
E. UV module wiper	Extra module on rack showing wiper
F. Controller	UV controller and interface
G. Controller interface	Operator interface
H. Module connections	Connections for modules
I. Lamp connections	Connections at end of lamps
J. Module electronics	Module electronics
K. Ballast connectors	Connections from module electronics to lamps ballasts

General Questions

As part of "Other Information" some potential questions are :

Were plant and UV system operations considered normal at the time of the tour?
Operation of Actiflo system (tertiary) not typical, was off during tour

What have been the main UV system design limitations/difficulties?
Actiflo not working means plant is running additional UV bank

- What have been the main UV system operational limitations/difficulties?

None with UV, modulation of water level noted, but not raised as issue by plant

- How have these been resolved (e.g., design and/or operational modifications)?

Plant to design rig for removing modules from channel (for Actiflo system)

- General recommendations/advice?

Plant very happy with service from Suntec, good response

Photo A – UV overview

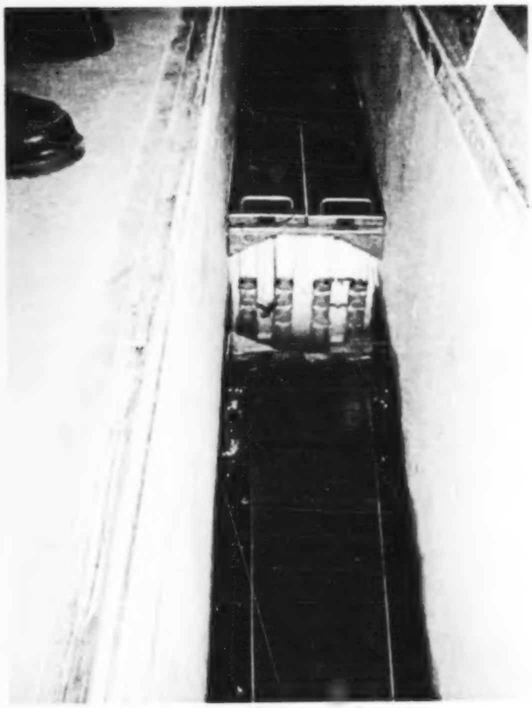


Photo B – Closeup lamp

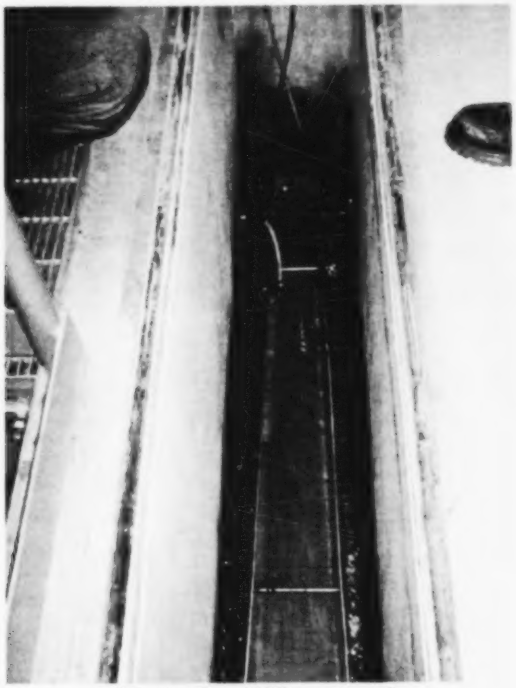


Photo C – Effluent weir

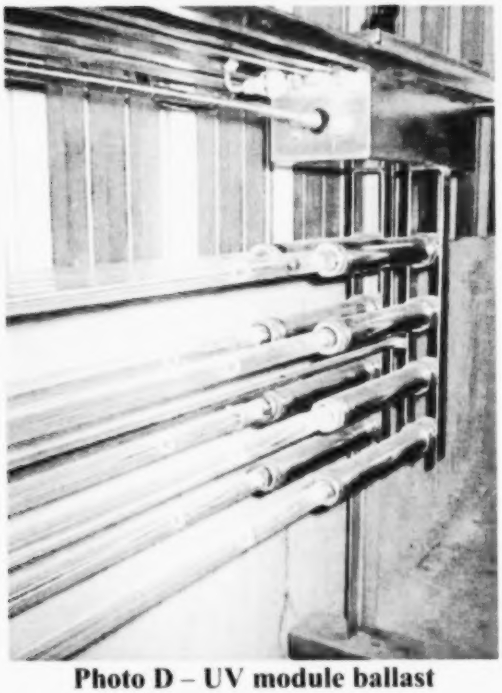


Photo D – UV module ballast

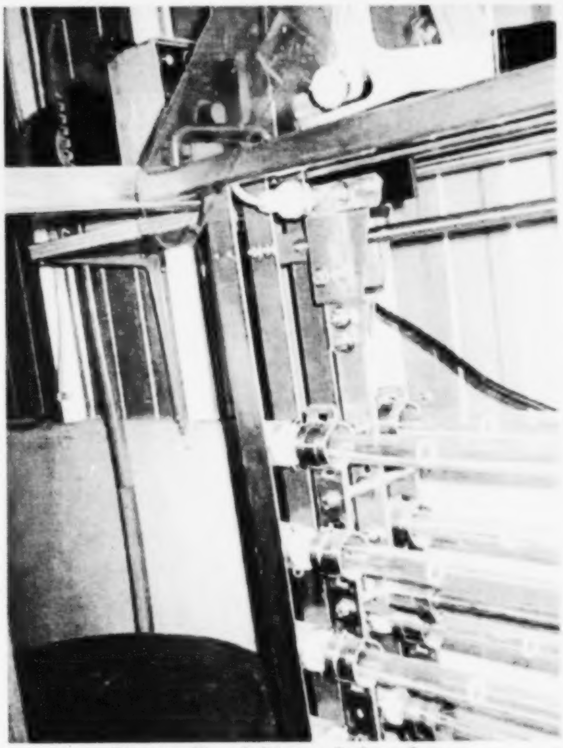


Photo E – UV module wiper

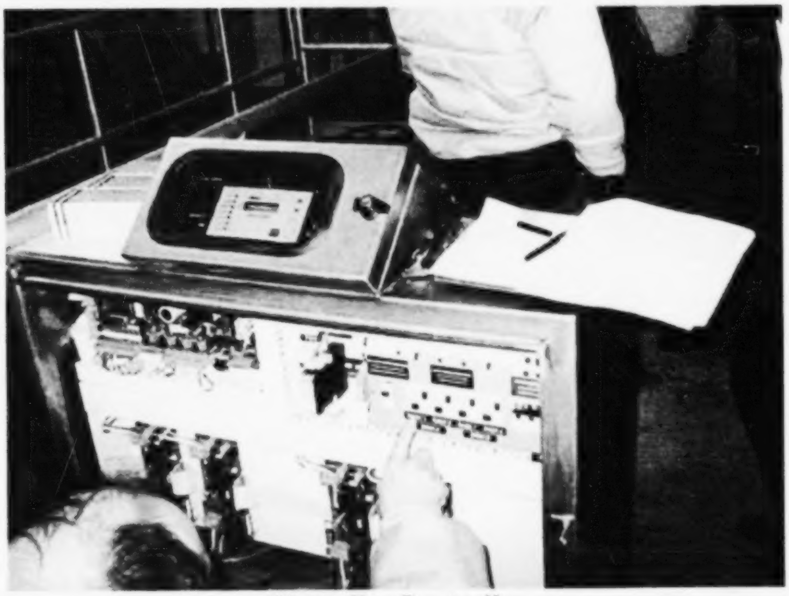


Photo F – Controller

LEAD BANK
A
B
BANK B
OFF
ON
LOCAL
REMOTE
BANK A
OFF
ON

Photo G – Controller interface

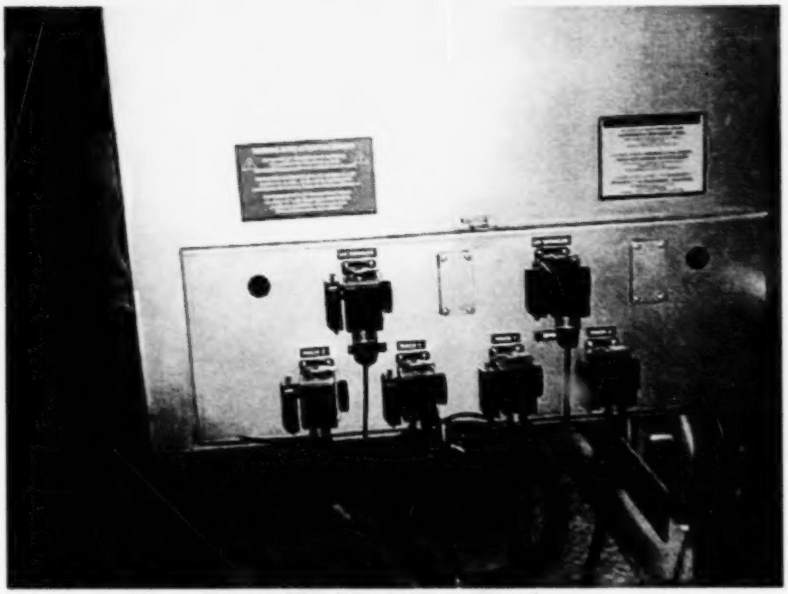


Photo H – Module connections

Photo I – Lamp connections

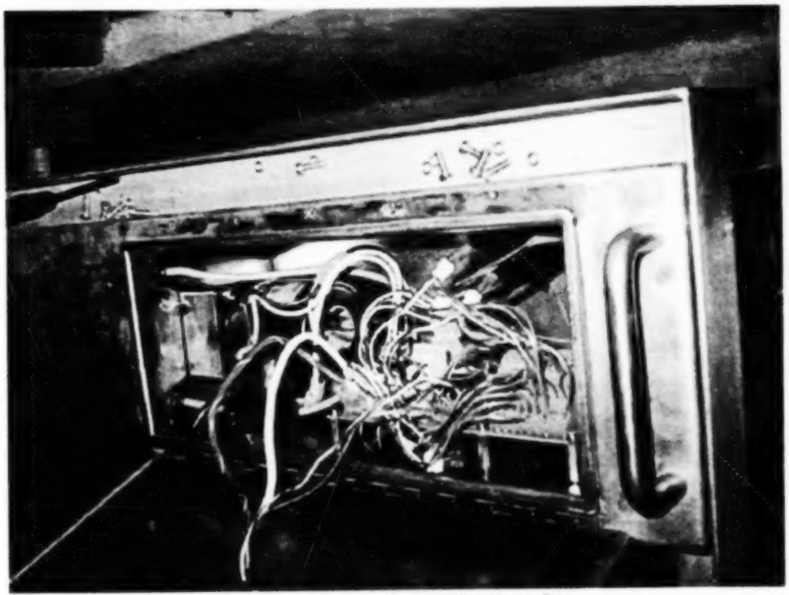


Photo J – Module electronics

Photo K – Ballast connectors

INFORMATION SHEET

GENERAL LOCATION:	Peterborough WWTP
Date:	March 6, 2002
Address:	425 Kennedy Road, Peterborough
Contact:	Mr. Zbigniew Bukala, Facility Engineer/Manager
Phone/Fax/email:	705-741-4910/705-743-0991 fax zbukala@peterborough.on.ca
FACILITY	
No. of Parallel Plants:	
Treatment Processes & Type:	Activated Sludge Plant, seasonal nitrification
Flows (current/design/peak):	60 MLD average/121 MLD[peak], 47.5 MLD current
Typical Influent (mg/L):	155 SS/132 BOD/2.53 TP/18.5 TKN
Typical Effluent (mg/L):	5.5 SS/3.5 CBOD/0.31 TP/0.98 & 3.04 NH3 (season)
W/W Temperature (oC):	
Effluent Limits:	200 cfu/100 mL (E.coli), W>120 MLD limit increases to 1000, 20/20 BOD/SS, 0.4 TP – plant uses dual-point chemical ferrous and alum, seasonal NH3-N
UV PROCESS MANUFACTURER:	Ultraguard
Type (LP/MP/LI/HI):	LP/HI
No. of lamps:	60
No. of Banks	2- 6 lamps per bank
No. of Channels:	6
Lamp rating (W):	approx. 1600 W input (5-4 W Germicidal)
Orientation (horiz or vert):	Vertical
Date Installed:	February 2002
Ballast #/location:	60 ballasts, on lamp submerged
Cleaning (manual/auto):	auto, felt wiper with cleaner, driven by electric motor
Cleaning Frequency:	to be set, system being commissioned
PARTICULARS	
Controls (system and instr):	System to be controlled based on flow and transmittance. Intensity sensor on each lamp
Control Parameters	Flow, transmittance, and modulation limits and lamp on time, ranges from 10 to 35 mW/cm2
Power Usage:	
Design UV Dose:	Various 18 min to 18 hr, often 3 hrs/ default 12 hr

INFORMATION SHEET	
UV PERFORMANCE	
Influent Bacteria (#/100 mls):	See pilot plant data, 30,000 to 50,000 E. coli, peak to about 4000,000
Effluent Bacteria (#/100 mls):	to 3 log reductions (pilot)
Transmittance (%):	high 60's to low 70s (pilot)
DESIGN CRITERIA	
Effluent SS (mg/L):	4 to 6 mg/L during pilot (peak 9 to 11 mg/L)
Transmittance:	65 % (high 60's to low 70's during piloting)
Operation:	up to 30°C
Guarantees (lamps/ballasts etc)	8000 hrs (7500-8000 also mentioned)
UV SYSTEM COSTS	
Capital Cost:	See document Equities Analyst – $1.15 mil
O&M Costs	
Lamps	
Electrical	
Cleaning	
Maintenance	
Replacement parts	
Replacement Costs	
Lamps	$2500
Ballasts	
Wipers	
OTHER INFORMATION	Additional info: Services 74,000 pop, high I/I in system Algae problem with pilot, may have to cover clarifiers Industries in town include Quaker Oats and Coca-Cola 4-year program included piloting, evaluation and delays Recently agreement with Clearwater for manufacturer and installation Magnetic switch (own) used for wiper, if fouled can operate wiper manually No auto switch on removal of lamps Control basically open channel at 50% output, close at 25% output plus min time of operation Main alarms, major, minor, status and manual/auto status – to SCADA Inputs to controller– flow and transmittance HMTL based interface

INFORMATION SHEET	
INFORMATION COLLECTED	WEFTEC 97 – Presentation by Karl Scheible Document – Relative Ratios of Competing UV systems TM CG&S – UV Disinfection-UltraGuard WEF reference – Channel Hydraulics
PHOTOS TAKEN (NO. AND DESCRIPTION)	
A. Plant layout	Aerial of plant site
B. UV Overview	Overview of UV area
C. Banks/channel	One bank from each channel
D. SLR	Single lamp reactor
E. Single bank	Single bank of SLRs
F. SLR connections	Connections to bank connector
G. Cleaning sol'n connection	Solenoid for cleaning sol'n
H. Cleaning sol'n storage	Storage tank for cleaning solution, using Simple Green diluted now instead of Citric Acid
I. Lamp	New lamp held up
J. Lamps on	View downstream through channel
K. Lamp replacement	Lid off lamps, showing fan
L. Transmittance instr.	Transmittance instrument
M. Controller	Interface for unit with plant
N. HMI	Interface computer for operations

GENERAL QUESTIONS

As part of "Other Information" some potential questions are:

- Were plant and UV system operations considered normal at the time of the tour?

No, system just being commisioned

- What have been the main UV system design limitations/difficulties?

None yet

- What have been the main UV system operational limitations/difficulties?

Delays in installation and startup, company changes should correct problem

- How have these been resolved (e.g., design and/or operational modifications)?

None yet

- General recommendations/advice? – Too early to comment

Photo A – Plant layout

Photo B – UV Overview

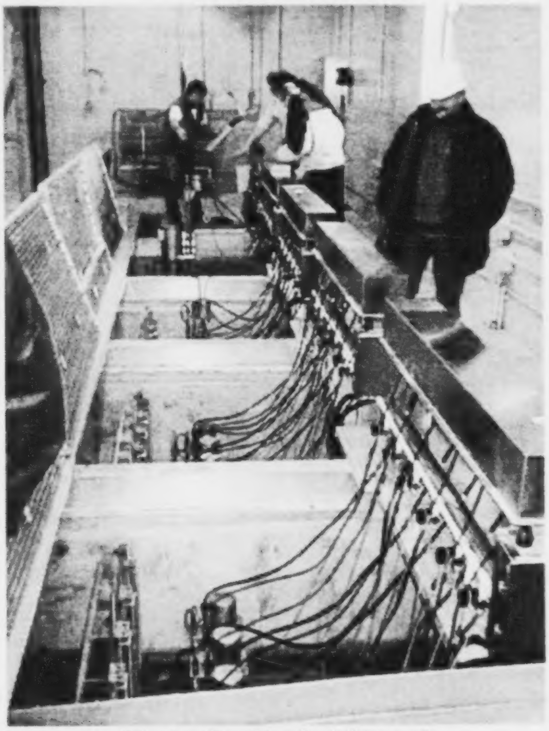


Photo C – Banks/channel

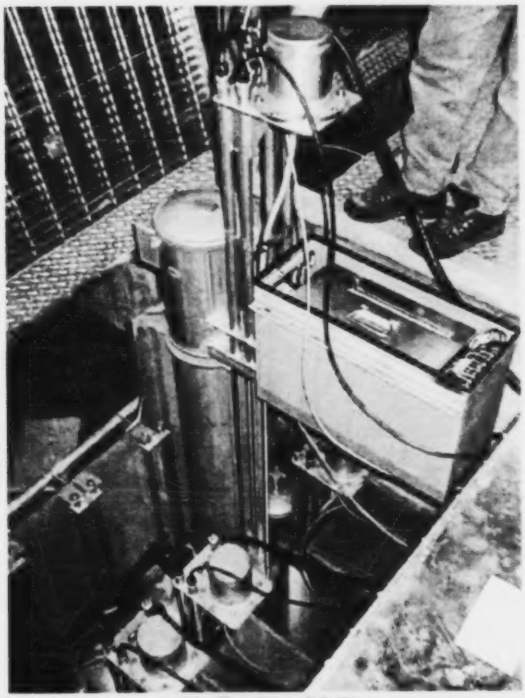


Photo D – SLR

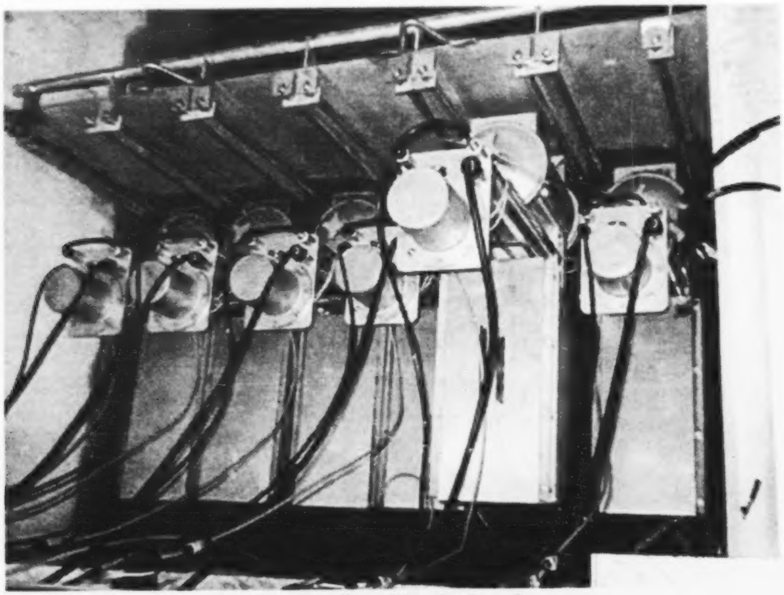


Photo E – Single bank

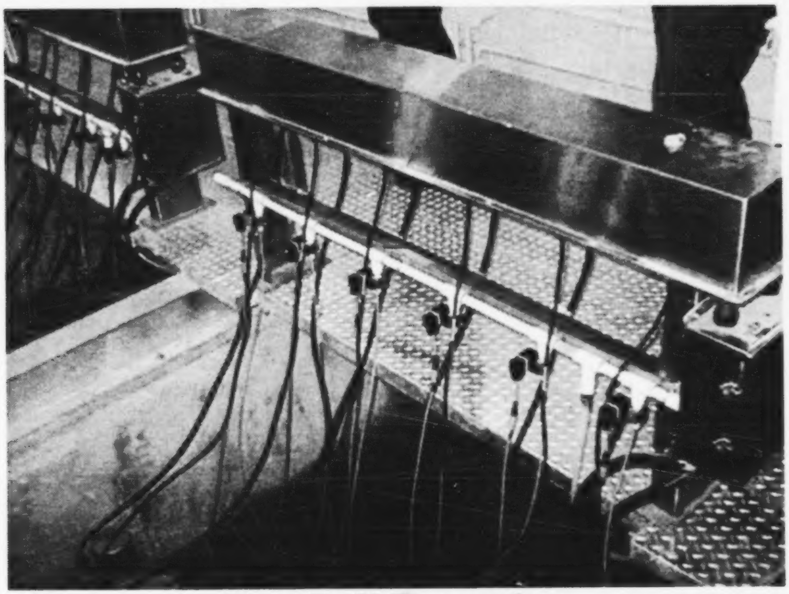


Photo F – SLR connections

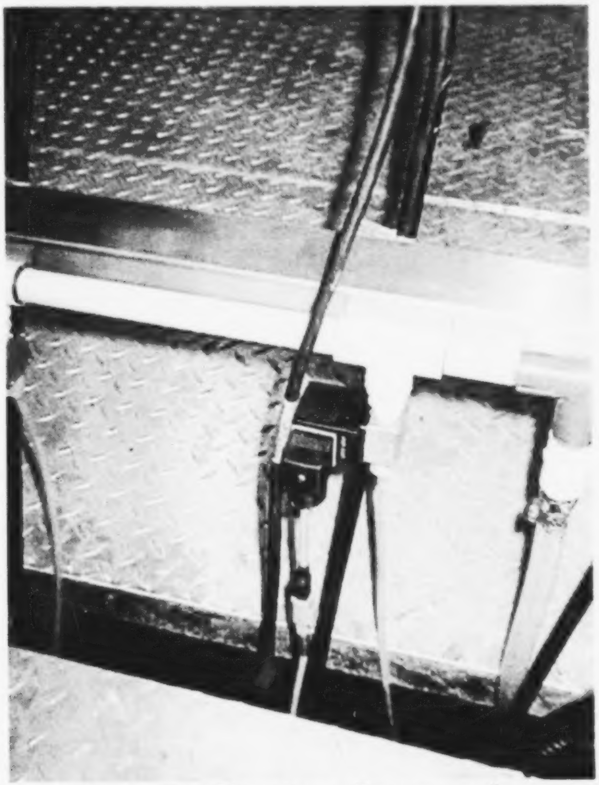


Photo G – Cleaning sol'n connection

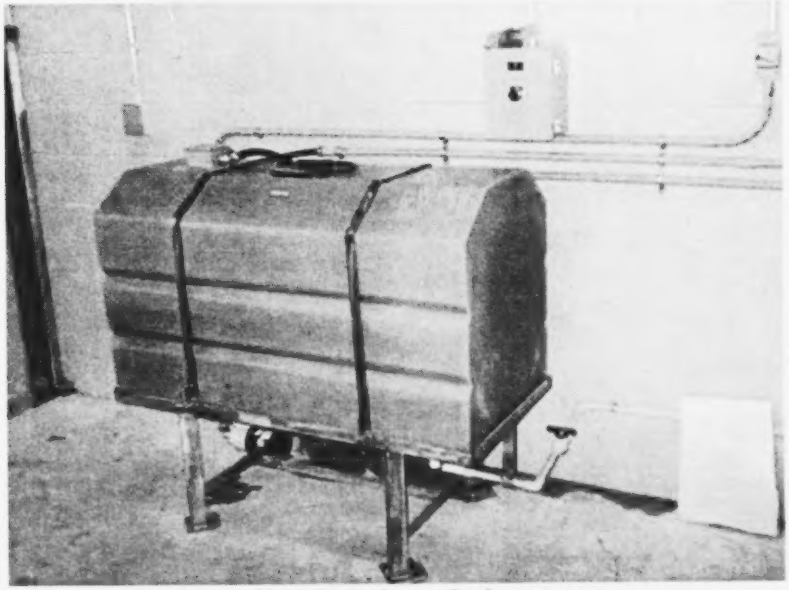


Photo H – Cleaning solution storage

Photo I – Lamp

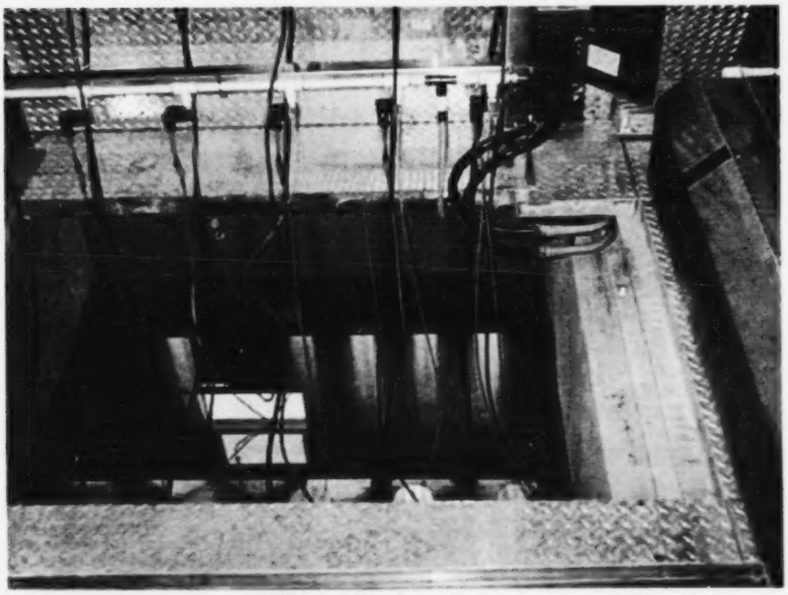


Photo J – Lamps on

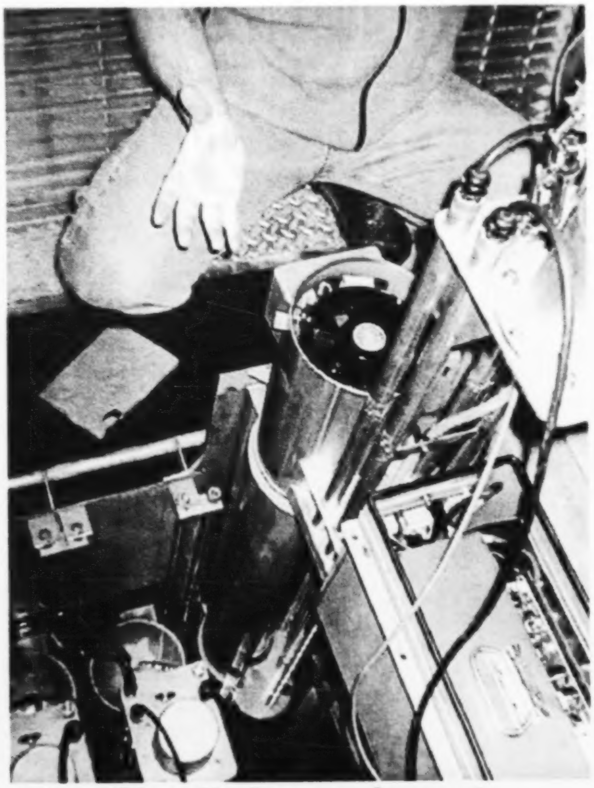


Photo K – Lamp replacement

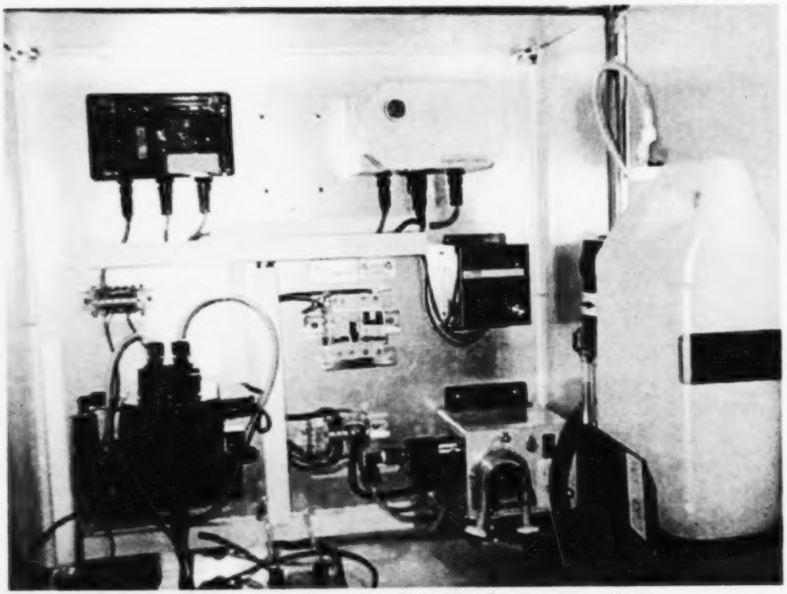


Photo L – Transmittance instrument

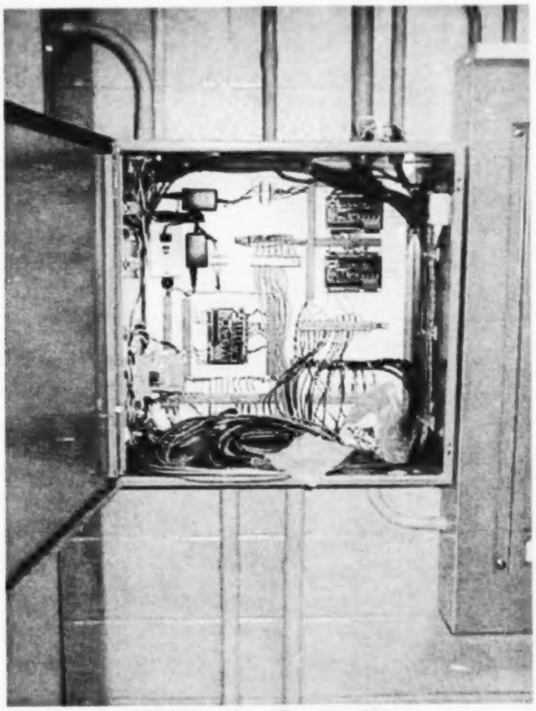


Photo M – Controller

Photo N – HMI Computer

INFORMATION SHEET

GENERAL LOCATION:	Georgetown WWTP	
Date:		
Address:	Georgetown, Region of Halton	
Contact:	Mr. Alvin Kiers/Superintendent	
Phone/Fax/email:	905-873-0515/905-624-7224	
FACILITY		
No. of Parallel Plants:	2 – old and new plant (A and B)	
Treatment Processes & Type:	Activated Sludge Plant	
Flows (current/design/peak):	14 to 18 MLD (22.7 MLD design)	
Typical Influent (mg/L):	150 SS/BOD	
Typical Effluent (mg/L):	meets effluent requirements	
W/W Temperature (°C):		
Effluent Limits:	5 SS, 5 BOD, 0.3 TP, 0.02 unionized ammonia-N, 0.002 Chlorine residual	
UV PROCESS		
Manufacturer:	Existing pre-Degremont unit, replacement with Suntec	
Type (LP/MP/LI/HI):	LP/LI vertical existing, LP/HI horiz proposed	
	Existing (installed 1989)	Proposed
No. of lamps:	560	192
No. of Banks	5 – 28 lamps/bank	1-6 mod/16 lamp/mod
No. of Channels:	4	2
Lamp rating (W):	100	200
Orientation (horiz or vert):	Vertical	Horizontal
Date Installed:	1989	February 2002
Ballast #/location:	1/lamp	
Cleaning (manual/auto):	Manual	auto
Cleaning Frequency:	Manual/air acid clean with citric acid 1-2/year	
PARTICULARS		
Controls (system and instr):	Current system is manually controlled, new will be flow paced, online transmissivity monitoring to be provided, UV intensity on each bank	
Control Parameters	Flow, Transmittance	
Power Usage:	45 kW max, modulation	
Design UV Dose:		

INFORMATION SHEET	
UV PERFORMANCE	None available
Influent Bacteria (#/100 mls):	
Effluent Bacteria (#/100 mls):	
Transmittance (%):	
DESIGN CRITERIA	
Effluent SS (mg/L):	10 mg/L maximum
Transmittance:	70%
Operation:	
Guarantees (lamps/ballasts etc)	8,760 hours on lamps
UV SYSTEM COSTS	New system only
Capital Cost:	Suntec quote $279,548 including taxes, including 2 channels, 12 lamp racks (modules) 2 power dist, 1 controller (LPX 200201661SWL)
O&M Costs	
Lamps	
Electrical	
Cleaning	3 boxes/ 48 lamps/box $5000 (Degremont) – original
Maintenance	
Replacement parts	
Replacement Costs	
Lamps	guarantee 8760 hours on lamps, $151
Ballasts	$251
Wipers	
OTHER INFORMATION	Other info: New system specs, 4310 length, 530 raised bottom, 1168 mm width, level control weir Spare parts to include 25% lamps, 25% ballasts, 25% quartz sleeves, 10% of lamp control modules, 25% wiper seals, one photocell, 2 intensity sensors [note amendment for seals, since wiper does not have seals]
INFORMATION COLLECTED	Parts of specification document
PHOTOS TAKEN (NO. AND DESCRIPTION)	
A. Plant overview	Aerial view of plant
B. Modules in channel	Module in operation in channel
C. Controller	Control panel with lamp status

INFORMATION SHEET	
D. Cleaning tanks	Cleaning tank, channel can also be used as cleaning vessel (gate up and downstream)
E. Effluent control weir	Level control
F. Lamp	Replacement lamp

General Questions

As part of "Other Information" some potential questions are :

- Were plant and UV system operations considered normal at the time of the tour?

Normal, old system still in operation

- What have been the main UV system design limitations/difficulties?

Manpower requirements

- What have been the main UV system operational limitations/difficulties?

Existing system age has been a problem, lack of control, number of lamps, electrical problems

- How have these been resolved (e.g., design and/or operational modifications)?

New system to be installed

- General recommendations/advice?

Photo A – Plant overview

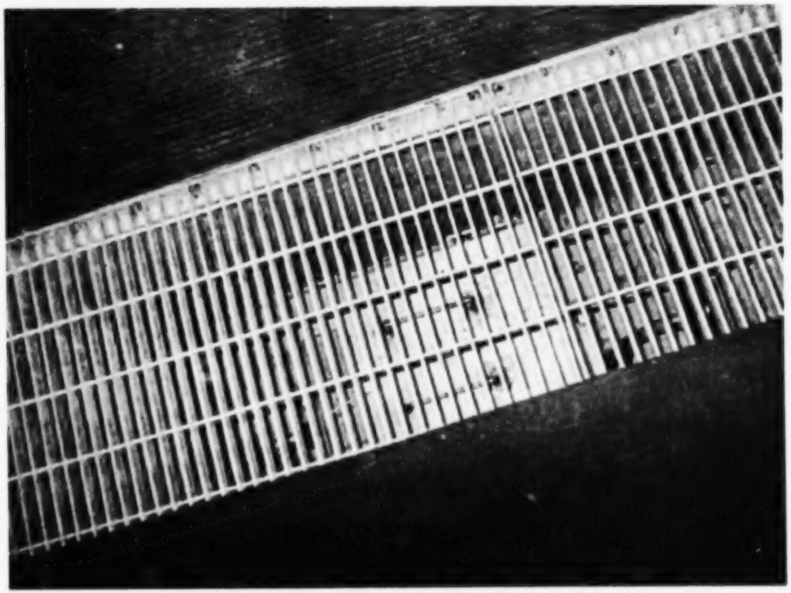


Photo B – Modules in channel

Photo C – Controller

Photo D – Cleaning tanks

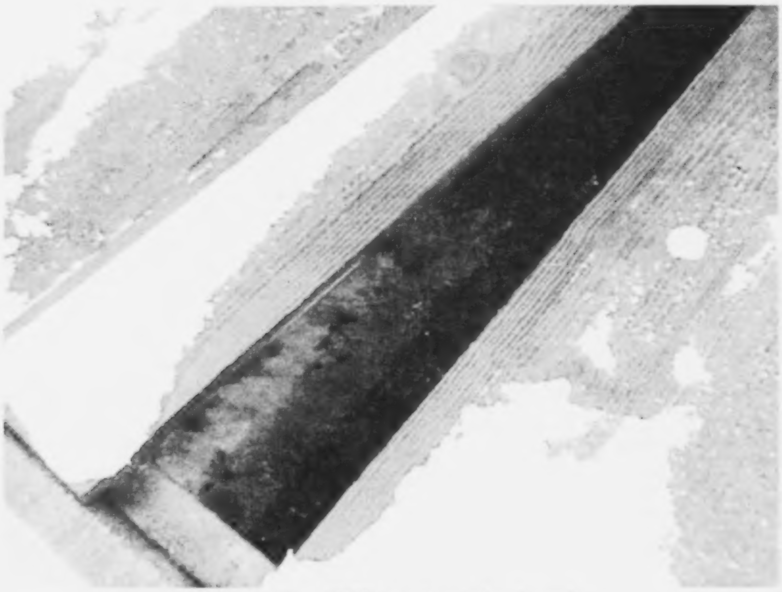


Photo E – Effluent control weir

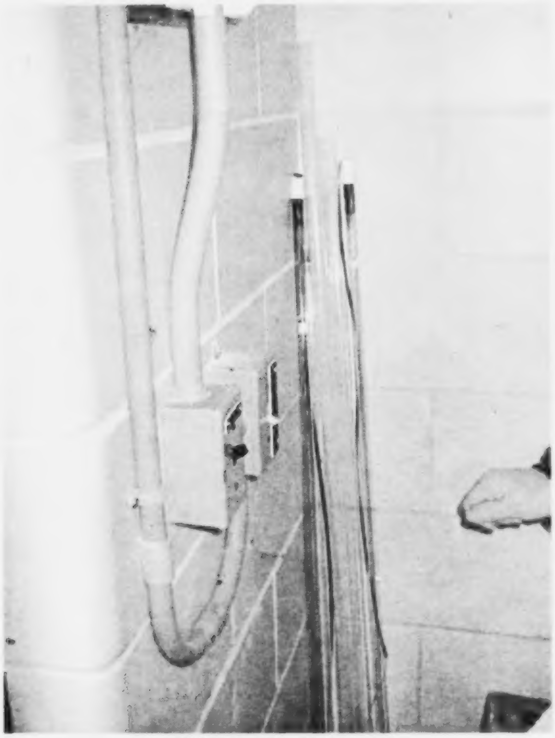


Photo F – Lamp

Hydromantis, Inc.
Consulting Engineers

210 Sheldon Drive
Cambridge, Ontario, Canada
N1T 1A8
Tel: 519-624-7223
Fax: 519-624-7224
E-mail:
info@hydromantis.com

Phone Record

Date:	January 2, 2002
Time of call:	4:00 pm
Who Talked:	Mike N
Copy to:	File
P.I.N.	332-05 E

CALL FR:	Mr. Rick Varner Bavham
Phone:	614-436-7999
Fax:	
E-mail:	

DETAILS:

Called Mr. Rick Varner to discuss the low pressure/high intensity UV system at his plant, the following main items were discussed, reference sheet from Degremont is attached:

1. Rick V operates two plants with Degremont high intensity UV systems. The first is a 6 mgd (23 MLD) average, 18 mgd peak (68 MLD) plant and system that was installed in 1997. The second is a 10 mgd (38 MLD) average, 30 mgd peak (114 MLD) system that was installed in 2001.
2. Both plants are activated sludge plant with tertiary filtrations
3. Units are operated seasonally from May 1 to October 31.
4. Systems are cleaned (out of channel) at end of session and once during season. Intensity usually drops through operating period to low of 80%
5. Both systems have air purge system available. Neither system has wiper
6. Both systems are covered
7. Headloss is 5 to 6 inch range (130 to 150 mm)
8. Very maintenance friendly system, much better than Trojan (according to Rick)
9. Lamps are purchased through supplier, lamps are lasting to close to limit expected
10. Modules have 40 lamps
11. Area is growing and more systems will be coming up, Rick will be recommending same UV systems for expansions due to his success with system and to provide standard system for Region.

1 ATTACHMENT – REFERENCE SHEET FROM DEGREMONT

2/14/2001 16:13 905-528-3428 DEGREMONT INC -1

ULTRAVIOLET LIGHT DISTINCTION EQUIPMENT REFERENCE SHEET

Equipment Manufacturer's Name: Infilco Degremont Inc.

Address: 2924 Emerywood Parkway Richmond, VA 23294

Telephone Number: (804) 756-7600

Design Engineer: Burgess & Niple Ltd.

Contact Person's Name: Vui Chang

Address: 5085 Reed Road, Columbus, Ohio 44320

Telephone Number: 614/459-2050

Installation Name Olentangy Environmental Control Center.

Location: County of Delaware, Ohio

Date of First Operation: September 1996

Treatment Plant Operator: Rick Varner

Telephone Number: 614-436-7999

Description of Secondary Treatment Process: Filtration

Design Flow (MGD): 18 Current Flow (MGD):

Number of UV Banks: 15

Number of Lamps per Bank: 40

Unfiltered Transmittance (%): 65

Effluent SS (mg/L): 18

UV Loading (gal/min-W): 0.27

UV Dose (µW-s/cm²): 27,570

Influent MPN: 200,000 (Max) (Average) 200,000

Effluent MPN: 200 (Max) 50 (Average) 10

Effluent Coliform Discharge Requirements: 200/100 ml, monthly average

END OF SECTION

Hydromantis, Inc.
Consulting Engineers

210 Sheldon Drive
Cambridge, Ontario, Canada
N1T 1A8
Tel: 519-624-7223
Fax: 519-624-7224
E-mail:
info@hydromantis.com

Phone Record

Date:	March 21, 2002
Time of call:	11:00 am
Who Talked:	Mike N
Copy to:	File
P.I.N.	461-01 E

CALLER:	Mr. Ed Roloson Bayham
Phone:	519-874-4761
Fax:	519-874-4101
E-mail:	eroloson@bayham.on.ca

DETAILS:

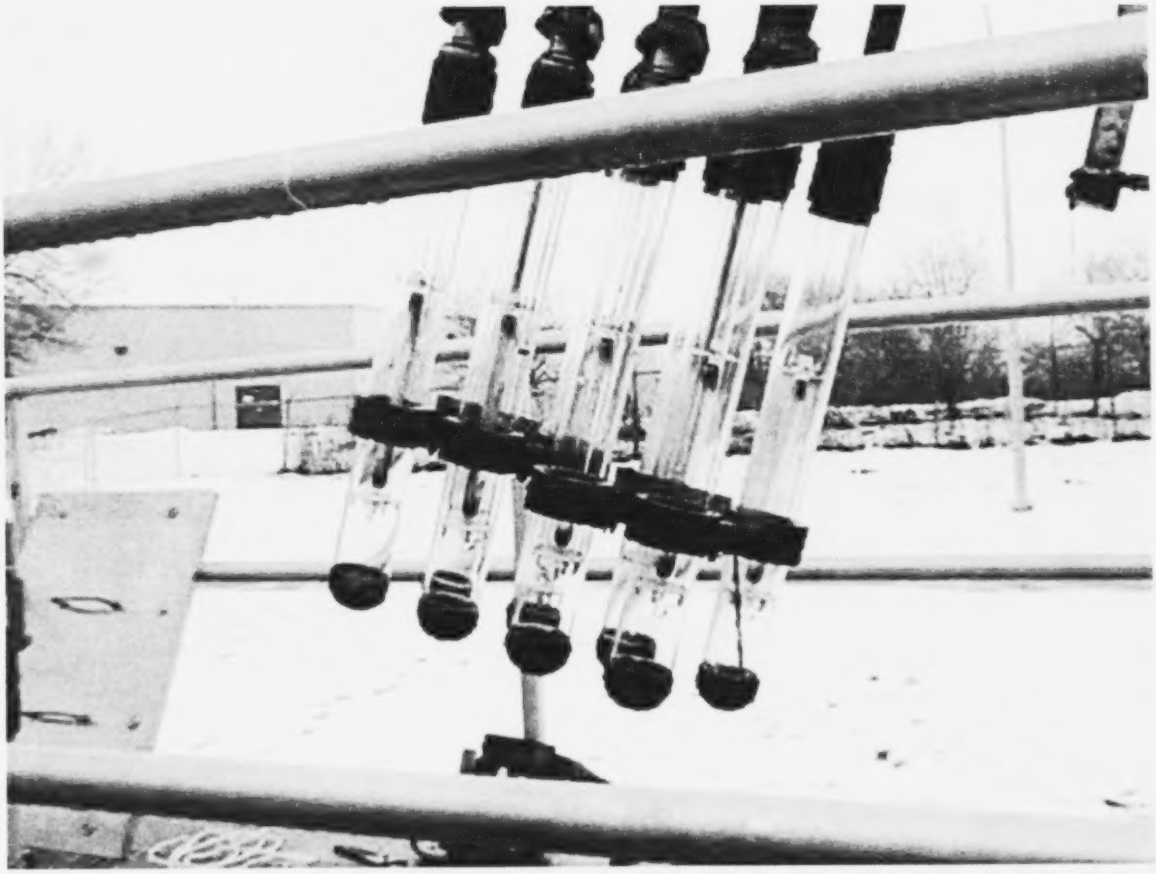
Mr. Roloson called back after sending few emails outlining our interest in his plant, main discussion included:

1. Plant has muffin and auger monster – auger screen system with upstream grinder
2. Poor performance with screen
3. Screen not effective in removing screenings, especially rages
4. Large amount of rag material evident in equalization basin
5. Plant has US Filter SBR (Jet Flow?), with old clarifier used as upfront or influent equalization, lots of rags are observed in this tank and on equipment
6. Ed believes, cutters on grinder are cutting too fine
7. Unit has been operating for greater than a year
8. Plant uses a small bin (probably 1 yd^3), collects screenings and grit, bin is still only half full – Ed believes this indicates lack of screenings being generated
9. Auger openings size is 5 mm
10. Unit has had no mechanical breakdowns
11. Supplier feels unit will work better when flows increase, current 500 m^3/d, expected doubling in next 9 months (design 1440 m^3/d)

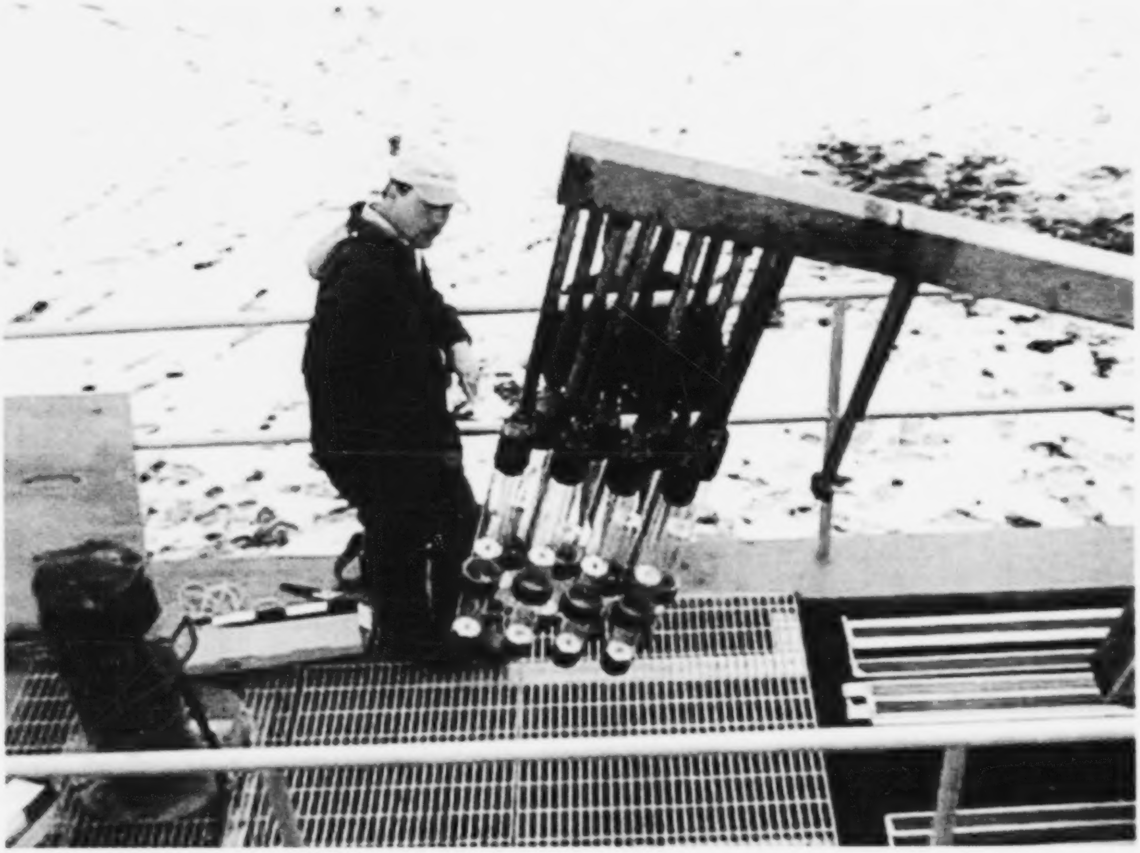
DETAILS:

12. There has been talk of adjusting cutters (less fine)
13. Auger monster can be set a two angles, either 45 or 30?, his at 45 shows material sliding down and out of unit – wonders about dropping it
14. Auger runs on timer (runs 2 minutes/cycle), solenoid opens for water. Unit is very dry at top, wear and noise seem excessive at top (hearing protection required)

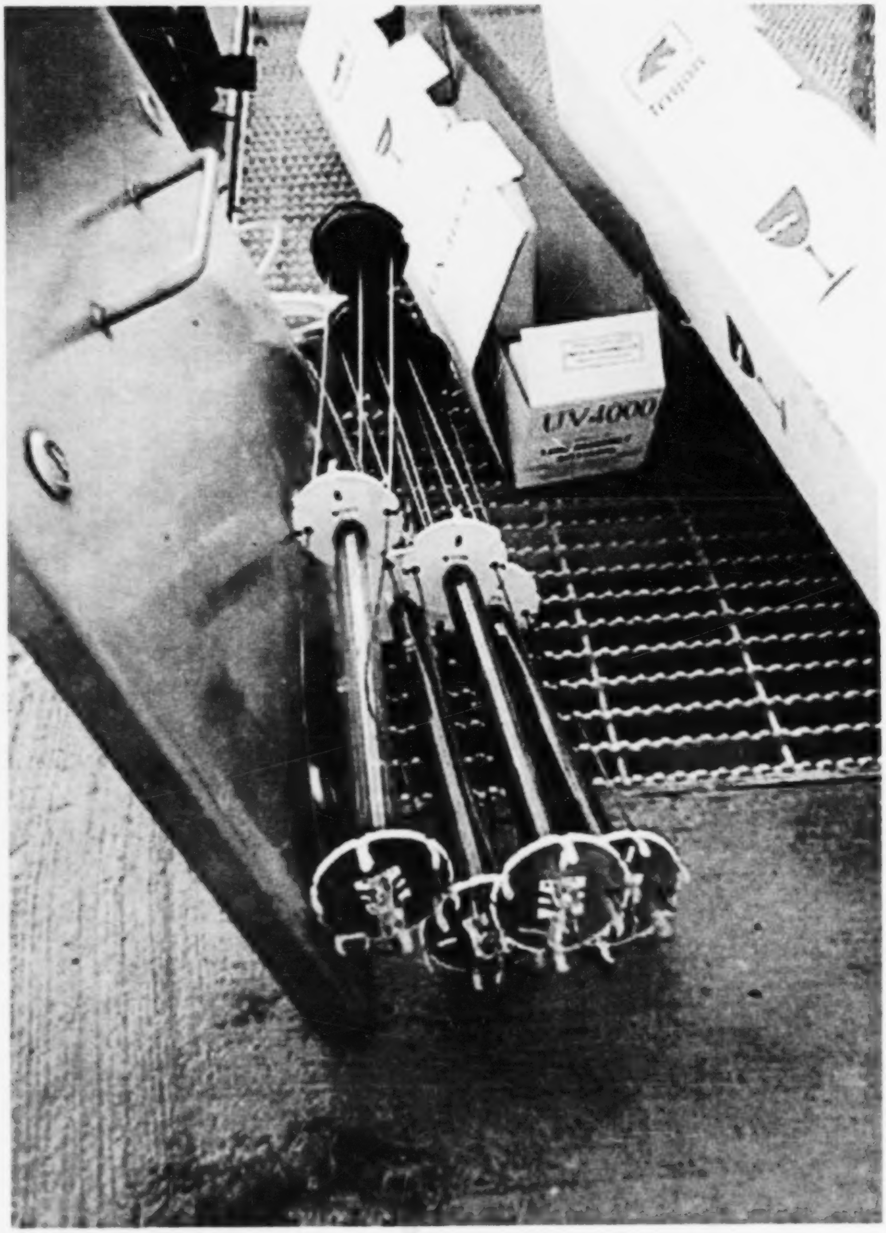
1. Wedeco unit in service for 1 year
2. Ed is "very disappointed with this unit"
3. Unit is manufactured in Vermont, US, panel constructed there was not CSA approved (did not pass) and had to be rewired in field, factory warranty was voided
4. Max operation has been 3 days without problem
5. Failures have been numerous, including wiper cleaning system (compressor replaced 3 to 4 times under warranty, many alarms not enough pressure for wipers, ballast problems (overheating until A/C installed in outdoor panel)
6. Bacteria kills are good
7. Control based on SBR cycle, runs at 50% min during off times, 5 min before decanting UV units ramp up to full output
8. No lamp problem
9. Configuration, 1 channel, 2 banks, 20 lamps total – 2x5 deep
10. Plant finds it difficult to put lamp in, buy as package with sleeve (pretty costly)
11. Lamps are 200-330 W rated
12. One condition of sale was local (i.e. Ont) supplier/technican, this has not been met
13. Technician come 1/month from Vermont
14. WEDECO has given extended warranty for 1 year, but system really not performing yet
15. Plant had an early Trojan 2000 (84-85) 2nd unit after Tillsonburg, 16 years of operation, better performance
16. New Trojan (i.e. high intensity) may also have problems, Ed indicated Belle River has 3000+ and has some problems
17. Plant has year round disinfection
18. Plant concerned about ice forming and breaking up during cycles that may damage lamps, hasn't happened yet, but warm winter
19. Sloughing over lamps seen at end of SBR cycle, corrected with manual valve to assist
20. US Filter SBR working great, Ed very happy with service from US Filter
21. Algae is a problem, at the plant, shading the trough helped, wipers (when working) do seem to help



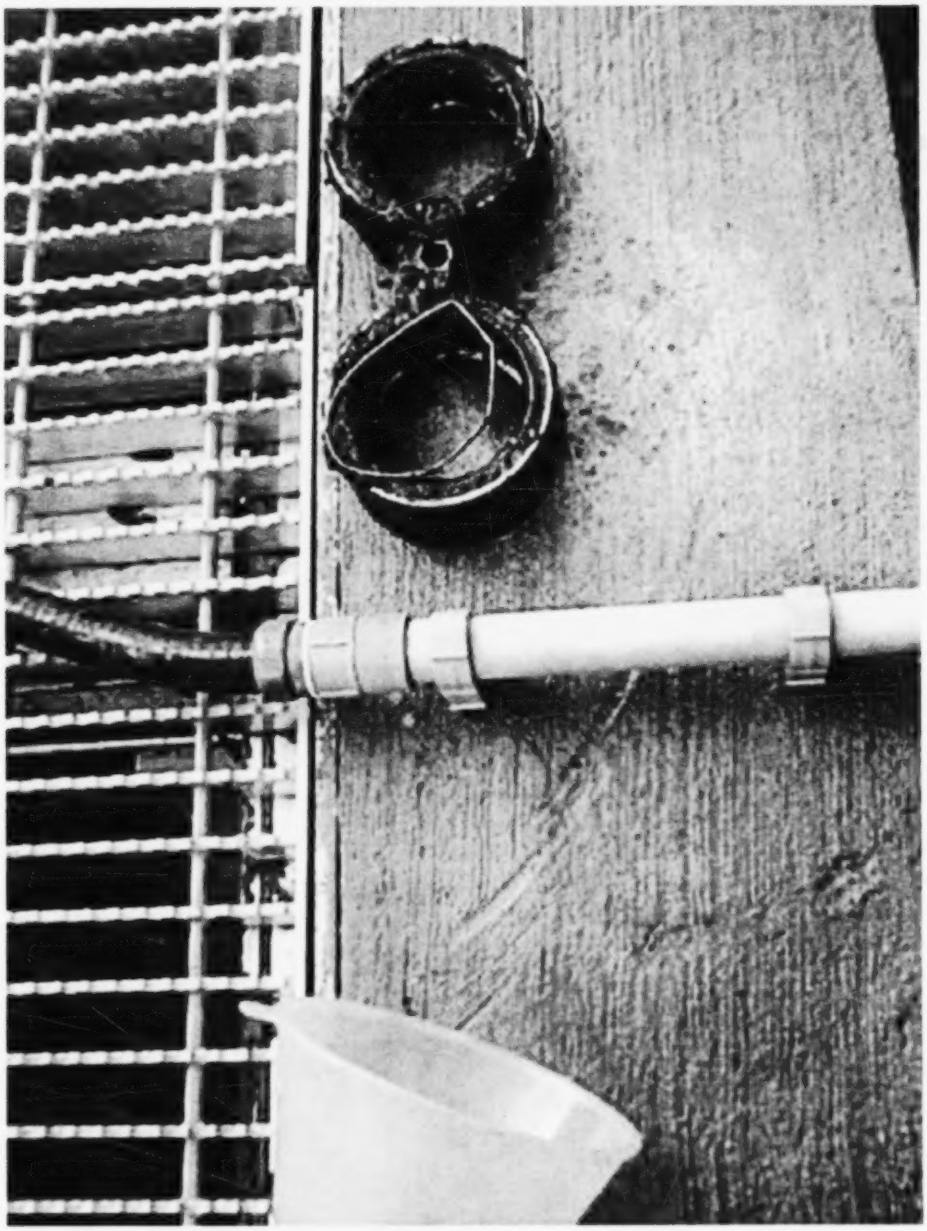
Trojan 4000 (Preston)



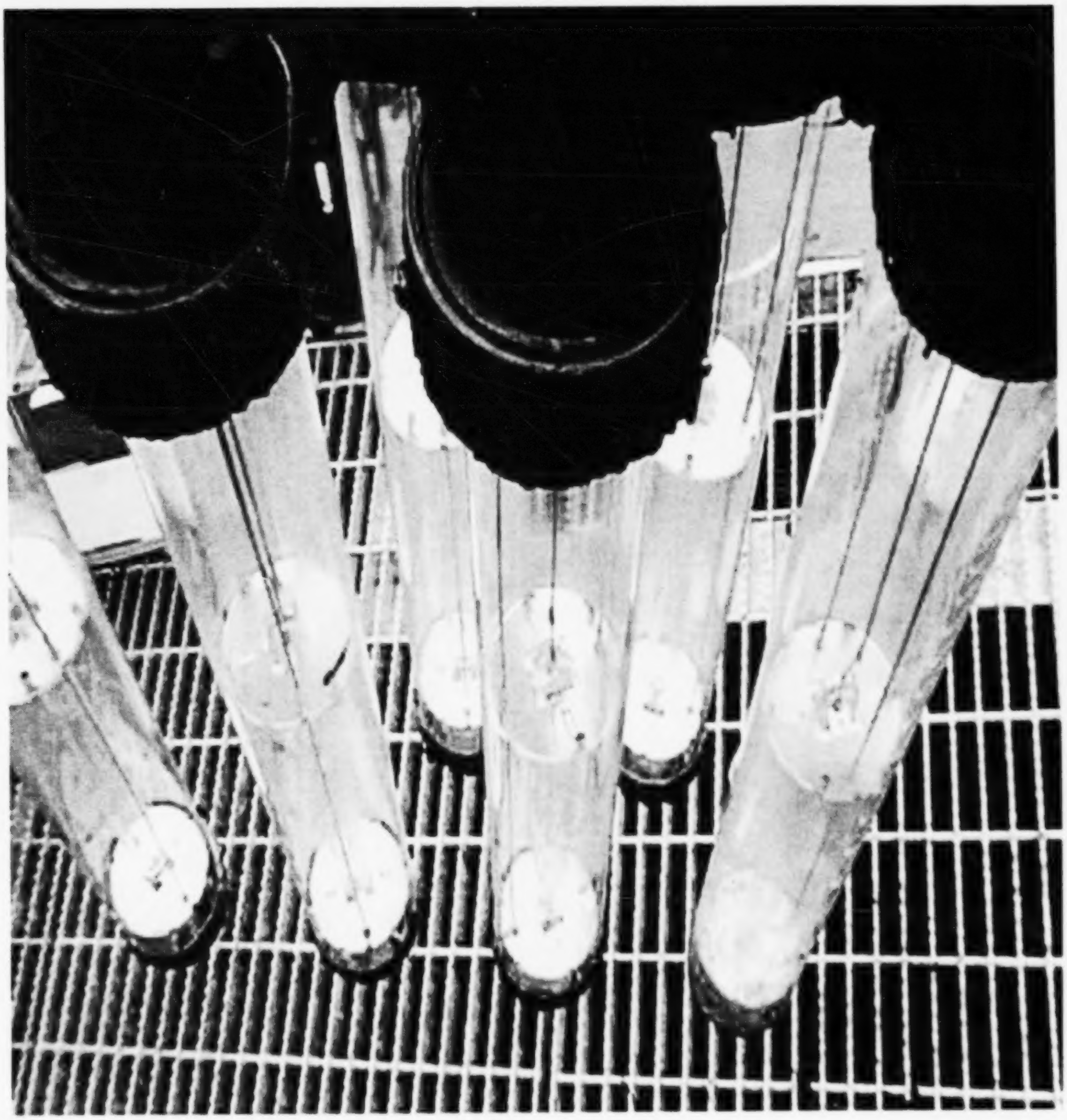
Trojan 4000 Bulb Replacement (Preston)



Trojan 4000 Used Lamps (Preston)



Trojan 4000 Wiper (Preston)



Trojan 4000 (Preston)

Trojan 4000 (Preston)

Collingwood Water Pollution Control Plant

Site Visit: November 14, 2001

Collingwood WPCP
3 Birch Street
Collingwood, Ontario
L9Y 2T8
Tel: (705)-445-1631
Fax: (705)-445-0852

Operating Company: Town of Collingwood

Contact: Don Green, Environmental Services Manager

Toured by: Don Green

CSO Facility: No (not at this site)

Flow: 6.46 mgd (24,548 m^3/d) design,
4.31 mgd (16,320 m^3/d) currently
UV Equipment: Medium Pressure, High Intensity
Manufacturer: Trojan Technologies
Model: Trojan 4000
Installed: 1998
System Description:

- In-channel installation, outside no covering, controls in adjacent building. Two banks with total of 60 bulbs (30 in each bank)

Description:
Seasonal disinfection required. No power measurement for unit. Lamps replaced this year (complete set) with approximate 6500 hours on bulbs – system 3 years in operation. Limiting transmittance 65%. Design intensity 80 mW/cm^2, dosage 24.1 $mW*s/cm^2$. Transmittance values vary from 50 to 80% averaging 70's at plant. Unit complete with wiper cleaner using lime away product. Plant pulls units to clean algae less than every month during operating season. Bacteria counts generally 10, lime 200 (E. coli).

OPERATIONAL ISSUES

Positive Issues:
Appears to operate well, few complaints. Low bacteria numbers, minor maintenance.

Negative Issues:
Cost of bulbs is high, but replacement after expected life.

Maintenance Requirements:
Minor.

Level of Satisfaction:
Satisfied.

Photo File

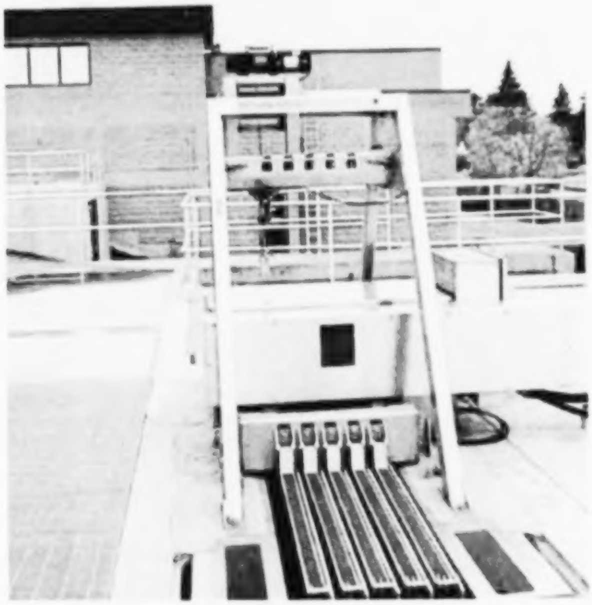


Photo 1 – View in line with channel

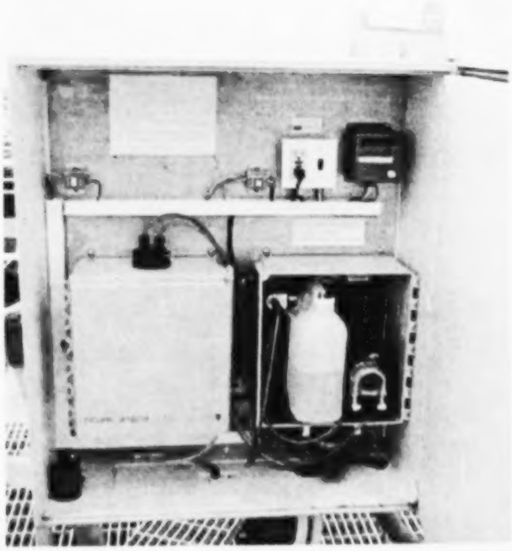


Photo 2 – Transmitance Sampling and Analysis

Photo 3 – Status indicator

Extract
Canada Gazette, Part I
December 4, 2004

DEPARTMENT OF THE ENVIRONMENT

Notice requiring the preparation and implementation of pollution prevention plans for inorganic chloramines and chlorinated wastewater effluents

Extrait
Gazette du Canada, Partie I
Le 4 décembre 2004

MINISTÈRE DE L'ENVIRONNEMENT

Avis requérant l'élaboration et l'exécution de plans de prévention de la pollution à l'égard des chloramines inorganiques et des eaux usées chlorées

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Published by the Queen's Printer for Canada, 2004

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Publié par l'Imprimeur de la Reine pour le Canada, 2004

DEPARTMENT OF THE ENVIRONMENT

CANADIAN ENVIRONMENTAL PROTECTION ACT, 1999

Notice requiring the preparation and implementation of pollution prevention plans for inorganic chloramines and chlorinated wastewater effluents

Whereas inorganic chloramines and chlorinated wastewater effluents are substances specified on the List of Toxic Substances in Schedule 1 of the *Canadian Environmental Protection Act, 1999*;

Whereas the Minister of the Environment published a Proposed Notice requiring the preparation and implementation of pollution prevention plans for ammonia dissolved in water, inorganic chloramines and chlorinated wastewater effluents in the *Canada Gazette*, Part I, on June 7, 2003;

Whereas persons were given the opportunity to file comments with respect to the Proposed Notice for a comment period of 60 days;

Whereas the Minister has considered all comments received;

MINISTÈRE DE L'ENVIRONNEMENT

LOI CANADIENNE SUR LA PROTECTION DE L'ENVIRONNEMENT (1999)

Avis requérant l'élaboration et l'exécution de plans de prévention de la pollution à l'égard des chloramines inorganiques et des eaux usées chlorées

Attendu que les chloramines inorganiques et les eaux usées chlorées sont des substances figurant sur la Liste des substances toxiques de l'annexe 1 de la *Loi canadienne sur la protection de l'environnement (1999)*;

Attendu que le ministre de l'Environnement a publié un projet d'avis requérant l'élaboration et l'exécution de plans de prévention de la pollution à l'égard de l'ammoniac dissous dans l'eau, des chloramines inorganiques et des eaux usées chlorées dans la Partie I de la *Gazette du Canada* le 7 juin 2003;

Attendu que toute personne a eu la possibilité d'envoyer des commentaires concernant le projet d'avis pendant une période de commentaires de 60 jours;

Attendu que le ministre a considéré tous les commentaires reçus;

Whereas this Notice is issued as an instrument respecting preventive and control action in relation to inorganic chloramines and chlorinated wastewater effluents in application of section 92 of the Act;

And whereas, the Minister has published a *Guideline for the Release of Ammonia Dissolved in Water Found in Wastewater Effluents*;

The Minister of the Environment hereby requires all persons or class of persons described in section 2 of this Notice to prepare and implement a pollution prevention plan in respect of inorganic chloramines and chlorinated wastewater effluents.

STÉPHANE DION
Minister of the Environment

1. Definitions

"Act" means the *Canadian Environmental Protection Act, 1999*.

"effluent" means untreated or treated wastewater that is released from the outfall(s) of a wastewater system, excluding combined sewer overflows from the wastewater system.

"inorganic chloramines" consists of three chemicals that are formed when chlorine and ammonia are combined in water: monochloramine (NH_2Cl), dichloramine ($NHCl_2$) and trichloramine (NCl_3).

"representative sampling" means the daily measurement of total residual chlorine concentration in the effluent under normal operating conditions of the wastewater treatment facility.

"surface water" means a lake, pond, marsh, creek, spring, stream, river, estuary or marine body of water, or other surface watercourse.

"total residual chlorine", or TRC, means the concentration of free chlorine and combined chlorine (including inorganic chloramines), expressed as Cl^-.

"wastewater" means a mixture of liquid wastes primarily composed of domestic sewage, that can also include other liquid wastes from industrial, commercial and institutional sources.

"wastewater system" means any works for the collection or treatment and release of wastewater or any part of such works.

2. Person or class of persons required to prepare and implement a pollution prevention plan

This Notice applies to any person who owns a wastewater system at the time of publication of this Notice where the effluent released during either 2004 or 2005 from that system to surface water is greater than or equal to 5 000 m^3 per day, based on an annual average, and where the concentration of total residual chlorine in the effluent released to surface water exceeds 0.02 mg/L in any sample during either 2004 or 2005, based on representative sampling.

3. Activities in relation to which the plan is to be prepared

The Minister requires all persons subject to this Notice to prepare and implement a pollution prevention plan in relation to the use of chlorine or chlorine compounds in wastewater systems and the release of chlorinated effluent to surface water.

Attendu que cet avis est publié comme un instrument concernant les mesures de prévention et de contrôle à l'égard des chloramines inorganiques et des eaux usées chlorées en application de l'article 92 de la Loi;

Et attendu que le ministre a publié une *Ligne directrice sur le rejet de l'ammoniac dissous dans l'eau se trouvant dans les effluents d'eaux usées*;

Le ministre de l'Environnement exige par la présente que toutes personnes ou catégories de personnes, telles qu'elles sont décrites à la section 2 de cet avis, élaborent et exécutent un plan de prévention de la pollution à l'égard des chloramines inorganiques et des eaux usées chlorées.

Le ministre de l'Environnement
STÉPHANE DION

1. Définitions

« chloramines inorganiques » comprend trois substances chimiques formées par la combinaison du chlore et de l'ammoniac dans l'eau : la monochloramine (NH_2Cl), la dichloramine ($NHCl_2$) et la trichloramine (NCl_3).

« chlore résiduel total », ou CRT, désigne la concentration de chlore libre et de chlore combiné (incluant les chloramines inorganiques), exprimée en Cl^-.

« eau de surface » désigne un lac, un étang, un marais, un ruisseau, une source, un cours d'eau, une rivière, un estuaire ou un plan d'eau marin, ou tout autre cours d'eau de surface.

« eaux usées » désigne un mélange d'eaux usées, composé principalement d'eau d'égout domestique, qui peut aussi contenir d'autres eaux usées de sources industrielles, commerciales et institutionnelles.

« échantillonnage représentatif » désigne la mesure quotidienne de la concentration de chlore résiduel total dans l'effluent, selon les conditions opérationnelles normales de l'installation de traitement des eaux usées.

« effluent » désigne les eaux usées traitées ou non traitées qui sont rejetées à l'exutoire d'un réseau d'assainissement, en excluant les débordements de réseaux d'égouts unitaires du réseau d'assainissement.

« Loi » désigne la *Loi canadienne sur la protection de l'environnement (1999)*.

« réseau d'assainissement » désigne tous les ouvrages servant à la collecte ou au traitement et au rejet des eaux usées, ou toute partie de ces ouvrages.

2. Personne ou catégorie de personnes qui sont tenues d'élaborer et d'exécuter un plan de prévention de la pollution

Cet avis s'applique à toute personne qui, au moment de la publication de cet avis, possède un réseau d'assainissement dont le rejet annuel moyen d'effluent dans les eaux de surface, soit en 2004 ou en 2005, est supérieur ou égal à 5 000 mètres cubes par jour et où la concentration du chlore résiduel total dans cet effluent est supérieur à 0,02 mg/L dans tout échantillon, soit en 2004 ou en 2005, tel qu'elle est déterminée d'après un échantillonnage représentatif.

3. Activités en fonction desquelles le plan devra être élaboré

Le ministre exige que toutes les personnes assujetties à cet avis élaborent et exécutent un plan de prévention de la pollution en ce qui concerne l'usage du chlore ou de composés chlorés dans les réseaux d'assainissement et le rejet d'effluents chlorés dans les eaux de surface.

4. Factors to be considered in preparing the plan

During the preparation of pollution prevention plans, the Minister requires all persons subject to this Notice to consider the following factors:

(1) Following detailed scientific assessments, inorganic chloramines and chlorinated wastewater effluents were found to be toxic under the Act. As such, these substances were added to the List of Toxic Substances in Schedule 1 of the Act. Persons subject to this Notice shall consider that these substances are "toxic" in accordance with the criteria set out in section 64 of the Act. In addition, the deposit of a deleterious substance of any type in water frequented by fish is prohibited by the *Fisheries Act*, under subsection 36(3), unless there is a regulation under subsection 36(5) of the *Fisheries Act* or under another federal law authorizing the deposit. With respect to inorganic chloramines and chlorinated wastewater effluents, there is no federal regulation at time of publication. Refer to section 15 of this Notice for links to the *Fisheries Act* and Compliance and Enforcement Policies of the *Fisheries Act* and the Act.

(2) "Pollution prevention", as defined in section 3 of the Act, means the use of processes, practices, materials, products, substances or energy that avoid or minimize the creation of pollutants and waste and reduce the overall risk to the environment or human health. Pollution prevention planning is a means of addressing the release, to the environment, of toxic substances or other pollutants. The result of pollution prevention planning is the implementation of preventive and/or control actions. In order to achieve the risk management objective set out in subsection 4(3), persons subject to this Notice shall consider the following activities when preparing and implementing their pollution prevention plans:

(*a*) Conducting process audits for chlorine by June 15, 2006, and implementing actions based on the audit findings by December 15, 2008, that minimize the use and release of chlorine or chlorine compounds. Refer to section 15 of this Notice for links to technical guidance.

(*b*) Implementing dechlorination or alternative disinfection technologies. Refer to section 15 of this Notice for links to technical guidance.

(3) The risk management objective for this Notice is to achieve and maintain a concentration of total residual chlorine that is less than or equal to 0.02 mg/L in the effluent released to surface water by December 15, 2009.

(4) The Canadian Council of Ministers of the Environment (CCME) agreed in November 2003 to develop a Canada-wide Strategy for the management of municipal wastewater effluents, which will address specific parameters and governance. The Strategy will be based on the following three cornerstones:

(*a*) harmonization of the regulatory framework;

(*b*) co-ordinated science and research; and

(*c*) an environmental risk management model.

The Strategy is expected to be completed by December 2006, after which it will be implemented by each jurisdiction. Environment Canada intends to use regulations under the *Fisheries Act* as its principal implementation tool to achieve effluent standards for wastewater treatment systems equivalent in performance to conventional secondary treatment, with additional treatment where required. The regulations will also address wastewater systems on federal and aboriginal lands. Refer to section 15 of this Notice for links to the CCME Web site and information on the Canada-wide Strategy.

(5) In order to ensure that the overall risk to the environment or human health is reduced, the pollution prevention plan prepared for this Notice should include, where relevant,

4. Facteurs à considérer lors de l'élaboration du plan

Le ministre exige que toutes les personnes assujetties à cet avis considèrent les facteurs suivants lors de l'élaboration de leur plan de prévention de la pollution :

(1) À la suite d'évaluations scientifiques approfondies, les chloramines inorganiques et les eaux usées chlorées ont été déclarées comme substances toxiques en vertu de la Loi. À ce titre, ces substances ont été ajoutées à la Liste des substances toxiques de l'annexe 1 de la Loi. Les personnes assujetties à cet avis doivent considérer que ces substances sont « toxiques » selon les critères établis à l'article 64 de la Loi. De plus, le dépôt d'une substance nocive dans les eaux où vivent les poissons est interdit par le paragraphe 36(3) de la *Loi sur les pêches* à moins qu'il n'y ait un règlement qui l'autorise, soit en vertu du paragraphe 36(5) de cette même loi ou d'une autre loi fédérale. En ce qui concerne le rejet des chloramines inorganiques et des eaux usées chlorées, il n'existe aucun règlement fédéral au moment de la publication de cet avis. Les adresses Internet des sites d'information sur la *Loi sur les pêches* et les politiques de conformité et d'application des dispositions de cette loi ainsi que de la *Loi canadienne sur la protection de l'environnement (1999)* se trouvent à l'article 15 de cet avis.

(2) La « prévention de la pollution », au sens de l'article 3 de la Loi, désigne l'utilisation de procédés, de pratiques, de matériaux, de produits, de substances ou de formes d'énergie qui, d'une part, empêchent ou réduisent au minimum la création de polluants et de déchets, et d'autre part, réduisent les risques d'atteinte à l'environnement ou à la santé humaine. La planification de la prévention de la pollution constitue un moyen de diminuer le rejet de substances toxiques ou d'autres polluants dans l'environnement. Le résultat de la planification de la prévention de la pollution comporte l'exécution de mesures préventives ou de contrôle. Afin d'atteindre l'objectif de gestion des risques, tel qu'il est décrit au paragraphe 4(3) de cet avis, les personnes assujetties à cet avis doivent considérer les activités suivantes lors de l'élaboration et de l'exécution de leur plan de prévention de la pollution :

a) Entreprendre des vérifications de procédés pour le chlore d'ici le 15 juin 2006 et mettre en œuvre des mesures basées sur les conclusions des vérifications qui minimisent l'utilisation et le rejet de chlore et de composés chlorés d'ici le 15 décembre 2008. Une liste de sites Internet ayant des informations techniques se trouve à l'article 15 de cet avis.

b) Appliquer des techniques de déchloration ou techniques alternatives de désinfection. Se référer à l'article 15 de cet avis pour consulter une liste de sites Internet présentant des documents techniques sur les options de prévention et de contrôle disponibles.

(3) L'objectif de gestion des risques de cet avis est d'atteindre et de maintenir une concentration de chlore résiduel total inférieure ou égale à 0,02 mg/L dans l'effluent rejeté dans les eaux de surface d'ici le 15 décembre 2009.

(4) Le Conseil canadien des ministres de l'environnement (CCME) a convenu en novembre 2003 d'élaborer une stratégie pancanadienne pour la gestion des effluents d'eaux usées municipales qui portera sur l'élaboration de paramètres spécifiques et sur des questions de gouvernance. La stratégie se fondera sur les trois pierres angulaires suivantes :

a) l'harmonisation du cadre réglementaire;

b) la coordination de la science et de la recherche;

c) un modèle de gestion des risques environnementaux.

On prévoit que la stratégie sera complétée d'ici décembre 2006, ce après quoi elle sera mise en œuvre par chaque instance. Environnement Canada a l'intention d'utiliser un

prevention and control actions that address risks posed by other substances that may be found in municipal wastewater effluent, in particular, the following substances which are specified in Schedule 1 of the Act:

(*a*) nonylphenol and its ethoxylates;

(*b*) effluents from textile mills that use wet processing;

(*c*) mercury;

(*d*) lead;

(*e*) hexavalent chromium compounds;

(*f*) inorganic cadmium compounds;

(*g*) inorganic arsenic compounds; and

(*h*) ammonia dissolved in water.

5. Period within which the pollution prevention plan is to be prepared

The Minister requires that the pollution prevention plan be prepared and implementation be initiated by June 15, 2007.

6. Period within which the pollution prevention plan is to be implemented

The Minister requires that the pollution prevention plan be implemented by June 15, 2010.

7. Content of the pollution prevention plan

Persons preparing the pollution prevention plan are to determine the appropriate content of their own plan; however, the plan must meet all the requirements of this Notice. It must also contain the information required to file the Declaration of Preparation referred to in section 9 and have the capacity to generate the information required to file the Declaration of Implementation referred to in section 10.

8. Requirement to keep plan

Under section 59 of the Act, all persons identified in section 2 shall keep a copy of the pollution prevention plan at the place in Canada in relation to which the pollution prevention plan is prepared. Where a single plan is prepared for more than one wastewater system, a copy of that plan must be kept at each location.

9. Declaration of Preparation

Under subsection 58(1) of the Act, persons identified in section 2 shall file, within 30 days after the end of the period for the preparation of the pollution prevention plan specified in section 5 or extended under section 13, a written *Declaration That a Pollution Prevention Plan Has Been Prepared and Is Being Implemented — Inorganic Chloramines and Chlorinated Wastewater Effluents*, using the form given in Schedule 1 of this Notice, to the Minister. Where a person has prepared a single plan for more than

règlement en vertu de la *Loi sur les pêches* comme son principal outil d'exécution afin que les réseaux d'assainissement atteignent des normes qui seront équivalentes, en performance, au rendement du traitement secondaire conventionnel, avec un traitement supplémentaire au besoin. Le règlement tiendra compte des systèmes d'eaux usées se trouvant sur les terres fédérales et autochtones. L'adresse Internet du site d'information sur la stratégie pancanadienne du CCME se trouve à l'article 15 de cet avis.

(5) Pour s'assurer de réduire le risque global pour l'environnement ou la santé humaine, le plan de prévention de la pollution élaboré pour répondre à cet avis devrait comprendre, s'il y a lieu, des mesures de prévention et de contrôle visant les risques posés par d'autres substances qui peuvent se trouver dans les effluents d'eaux usées municipales, en particulier les substances suivantes figurant à l'annexe 1 de la Loi :

a) le nonylphénol et ses dérivés éthoxylés;

b) les effluents des usines de textile qui utilisent des procédés de traitement au mouillé;

c) le mercure;

d) le plomb;

e) les composés de chrome hexavalent;

f) les composés inorganiques de cadmium;

g) les composés inorganiques d'arsenic;

h) l'ammoniac dissous dans l'eau.

5. Délai imparti pour l'élaboration du plan de prévention de la pollution

Le ministre exige que le plan de prévention de la pollution soit élaboré et que l'exécution en soit commencée au plus tard le 15 juin 2007.

6. Délai imparti pour l'exécution du plan de prévention de la pollution

Le ministre exige que l'exécution du plan de prévention de la pollution soit exécutée au plus tard le 15 juin 2010.

7. Contenu du plan de prévention de la pollution

Les personnes chargées de l'élaboration du plan doivent en déterminer le contenu; toutefois, le plan doit satisfaire à toutes les exigences de cet avis. Il doit également inclure les informations exigées pour déposer la déclaration confirmant l'élaboration à laquelle l'article 9 se réfère et pouvoir générer les informations exigées pour déposer la déclaration confirmant l'exécution à laquelle l'article 10 se réfère.

8. Obligation de conserver une copie du plan

En vertu de l'article 59 de la Loi, les personnes identifiées à l'article 2 de cet avis doivent conserver une copie du plan de prévention de la pollution au lieu, au Canada, en faisant l'objet. Lorsqu'un seul plan est élaboré pour plusieurs réseaux d'assainissement, une copie de ce plan doit être conservée à l'emplacement de chacun des réseaux d'assainissement en faisant objet.

9. Déclaration confirmant l'élaboration

En vertu du paragraphe 58(1) de la Loi, les personnes identifiées à l'article 2 doivent déposer par écrit auprès du ministre, dans les 30 jours suivant la fin du délai fixé à l'article 5 pour l'élaboration du plan ou, selon le cas, prorogé en vertu de l'article 13, une *Déclaration confirmant qu'un plan de prévention de la pollution a été élaboré et qu'il est en cours d'exécution — chloramines inorganiques et eaux usées chlorées*, en utilisant le formulaire fourni à l'annexe 1 de cet avis. Dans le cas où une

one wastewater system, a separate Declaration of Preparation must be filed for each of those systems. Section 17 provides further information on completing and filing this form.

10. Declaration of Implementation

Under subsection 58(2) of the Act, persons identified in section 2 shall file, within 30 days after the completion of the implementation of the plan specified in section 6 or extended under section 13, a written *Declaration That a Pollution Prevention Plan Has Been Implemented — Inorganic Chloramines and Chlorinated Wastewater Effluents*, using the form given in Schedule 5 of this Notice, to the Minister. Where a person has prepared a single plan for more than one wastewater system, a separate Declaration of Implementation must be filed for each of those systems. Section 17 provides further information on completing and filing this form.

11. Filing of amended declarations

Under subsection 58(3) of the Act, where a person specified in section 2 has filed a declaration under section 9 or 10, and the declaration contains information which, at any time after the filing, has become false or misleading, that person shall file an amended declaration to the Minister within 30 days after the time that the information became false or misleading, using the appropriate form referred to in section 9 or 10.

12. Use of a plan prepared or implemented for another purpose

Under subsection 57(1) of the Act, a person may use an existing pollution prevention plan or other plan in respect of pollution prevention prepared or implemented for another purpose to satisfy the requirements of sections 2 to 8 of this Notice. Under subsection 57(2) of the Act, where a person uses a plan that does not meet all the requirements of this Notice, the person shall amend the plan so that it meets all of those requirements or prepare an additional plan that meets the remainder of those requirements. Persons using existing plans must nonetheless file a Declaration of Preparation under section 9, a Declaration of Implementation under section 10, and any amended declarations under section 11.

13. Extension of time

Under subsection 56(3) of the Act, where the Minister is of the opinion that further time is necessary to prepare the plan as specified in section 5 or to implement the plan as specified in section 6, the Minister may extend the period for a person who submits a written *Request for Time Extension — Inorganic Chloramines and Chlorinated Wastewater Effluents*, using the form given in Schedule 3 of this Notice, before the expiry of the date referred to in the applicable section 5 or section 6 or before the expiry of any extended period. Section 17 provides further information on completing and filing this form.

14. Application for waiver of factors to consider

Under subsection 56(5) of the Act, the Minister may waive the requirement for a person to consider a factor specified in section 4 where the Minister is of the opinion that it is not reasonable or practicable to consider that factor on the basis of reasons provided by that person when submitting a written *Request for Waiver of the Requirement to Consider a Factor or Factors — Inorganic*

personne a élaboré un plan unique pour plus d'un réseau d'assainissement, une déclaration confirmant l'élaboration séparée doit être déposée pour chacun des réseaux. Les détails sur la façon de produire et de déposer ce formulaire se trouvent à l'article 17.

10. Déclaration confirmant l'exécution

En vertu du paragraphe 58(2) de la Loi, les personnes identifiées à l'article 2 doivent déposer par écrit auprès du ministre, dans les 30 jours suivant la fin de la période de l'exécution du plan comme prescrit à l'article 6 ou, selon le cas, prorogé en vertu de l'article 13, une *Déclaration confirmant l'exécution d'un plan de prévention de la pollution — chloramines inorganiques et eaux usées chlorées*, en utilisant le formulaire fourni à l'annexe 5 de cet avis. Dans le cas où une personne a élaboré un plan unique pour plus d'un réseau d'assainissement, une déclaration confirmant l'exécution doit être déposée individuellement pour chacun des systèmes. Les détails sur la façon de produire et de déposer ce formulaire se trouvent à l'article 17.

11. Dépôt d'une déclaration corrective

En vertu du paragraphe 58(3) de la Loi, lorsqu'une personne, telle qu'elle est identifiée à l'article 2 de cet avis, dépose une déclaration confirmant l'élaboration ou l'exécution dont il est question à l'article 9 ou 10, et que la déclaration contient des renseignements qui deviennent faux ou trompeurs à une date ultérieure, cette personne doit déposer auprès du ministre une déclaration corrective dans un délai de 30 jours de la date où les renseignements sont devenus faux ou trompeurs, en utilisant le formulaire approprié mentionné à l'article 9 ou 10, selon le cas.

12. Utilisation d'un plan élaboré ou exécuté à une autre fin

En vertu du paragraphe 57(1) de la Loi, une personne peut utiliser un plan de prévention de la pollution déjà élaboré ou exécuté à d'autres fins pour satisfaire aux exigences des articles 2 à 8 de cet avis. En vertu du paragraphe 57(2) de la Loi, lorsqu'une personne utilise un plan qui ne répond pas à toutes les exigences de cet avis, cette personne doit modifier le plan afin qu'il réponde à toutes ces exigences ou élaborer un plan complémentaire qui satisfait aux exigences non remplies. Une personne qui utilise un plan existant doit néanmoins déposer une déclaration confirmant l'élaboration conformément à l'article 9, une déclaration confirmant l'exécution conformément à l'article 10 et, le cas échéant, toute déclaration corrective dont il est question à l'article 11.

13. Prorogation du délai

En vertu du paragraphe 56(3) de la Loi, lorsque le ministre estime qu'un délai plus long est nécessaire pour l'élaboration du plan, tel qu'il est précisé à l'article 5, ou pour l'exécution du plan, tel qu'il est précisé à l'article 6, le ministre peut proroger le délai pour une personne qui présente par écrit une *Demande de prorogation du délai — chloramines inorganiques et eaux usées chlorées*, en utilisant le formulaire fourni à l'annexe 3 de cet avis, avant la date dont il est question à l'article 5 ou à l'article 6 ou avant l'expiration de toute autre prorogation de délai. Les détails sur la façon de produire et de déposer ce formulaire se trouvent à l'article 17.

14. Demande de dérogation à l'obligation de prendre en considération certains facteurs

En vertu du paragraphe 56(5) de la Loi, lorsque le ministre estime qu'il est déraisonnable ou impossible de tenir compte d'un facteur précisé à l'article 4, le ministre peut approuver une dérogation à l'obligation de tenir compte de ce facteur pour une personne qui présente par écrit une *Demande de dérogation à l'obligation de prendre en considération certains facteurs —*

Chloramines and Chlorinated Wastewater Effluents, using the form given in Schedule 2 of this Notice. Such a request must be made before June 15, 2007, or before the expiry of any extended period. Section 17 provides further information on completing and filing this form.

15. Additional information

Environment Canada has published a *Guideline for the Release of Ammonia Dissolved in Water Found in Wastewater Effluents*. To obtain a copy of the Guideline, refer to the CEPA Registry Web site at www.ec.gc.ca/ceparegistry.

To obtain a copy of the document *Review of Municipal Sewage Effluent Chlorination/Dechlorination Principles, Technologies and Practices* (November 2003), refer to Environment Canada's Georgia Basin Web site at www.pyr.ec.gc.ca/georgiabasin/reports_e.htm.

To obtain a copy of the document *U.V. Guidance Manual for Municipal Wastewater Treatment Plants in Canada* (October 2003), refer to the Great Lakes Sustainability Fund Web site at http://sustainabilityfund.gc.ca or contact the Manager, Great Lakes Sustainability Fund, 867 Lakeshore Road, Burlington, Ontario L7R 4A6, (905) 336-6273.

To obtain a copy of the document *Guidance Manual for Sewage Treatment Plant Process Audits*, refer to the Great Lakes Sustainability Fund Web site at http://sustainabilityfund.gc.ca or contact the Manager, Great Lakes Sustainability Fund, 867 Lakeshore Road, Burlington, Ontario L7R 4A6, (905) 336-6273.

To obtain a copy of the *Fisheries Act*, refer to the Department of Justice Web site at http://laws.justice.gc.ca/en/f-14. For more information on the compliance and enforcement policies of the *Fisheries Act* and the *Canadian Environmental Protection Act, 1999*, visit the Environmental Law Enforcement Web site at www.ec.gc.ca/ele-ale/policies/policies_e.asp.

Additional information on pollution prevention and preparing pollution prevention plans is available from the National Office of Pollution Prevention Web site at www.ec.gc.ca/nopp, the Canadian Pollution Prevention Information Clearinghouse Web site at www.ec.gc.ca/cppic, and Environment Canada's regional offices.

To obtain information regarding the CCME Canada-wide strategy for the management of municipal wastewater effluents, visit the CCME Web site at www.ccme.ca/initiatives/water.html?category_id=81.

16. Reference code

For administrative purposes, all communication with Environment Canada concerning this Notice shall refer to the following reference code: P2CLMWWE.

17. Declarations and forms

Declarations and forms referred to in this Notice are available from and are to be submitted to

National Office of Pollution Prevention
c/o CEPA Implementation and Innovation Division
Environment Canada
351 Saint-Joseph Boulevard, 13th Floor
Gatineau, Quebec K1A 0H3

Alternatively, the forms can be completed electronically at the Web site listed below.

chloramines inorganiques et eaux usées chlorées, en utilisant le formulaire fourni à l'annexe 2 de cet avis. Une telle demande doit être faite avant le 15 juin 2007 ou avant l'expiration de tout délai prorogé. Les détails sur la façon de produire et de déposer ce formulaire se trouvent à l'article 17.

15. Information supplémentaire

Environnement Canada a publié une *Ligne directrice sur le rejet de l'ammoniac dissous dans l'eau se trouvant dans les effluents d'eaux usées*. Pour obtenir une copie de cette ligne directrice, visitez le site Web du Registre de la LCPE à l'adresse www.ec.gc.ca/RegistreLCPE.

Pour obtenir une copie du document *Examen des principes, des techniques et des procédés de chloration et de déchloration des effluents des eaux usées municipales* (novembre 2003), visitez le site Web du Bassin de Georgia d'Environnement Canada à l'adresse www.pyr.ec.gc.ca/georgiabasin/reports_F.htm.

Pour obtenir une copie du document *Technologie de la désinfection par rayonnement ultraviolet appliquée aux usines de traitement des eaux usées municipales au Canada* (octobre 2003), visitez le site Web du Fonds de durabilité des Grands Lacs à l'adresse http://sustainabilityfund.gc.ca ou communiquez avec le Gestionnaire, Fonds de durabilité des Grands Lacs, 867, chemin Lakeshore, Burlington (Ontario) L7R 4A6, (905) 336-6273.

Pour obtenir une copie du document *Guide relatif aux vérifications des procédés des usines de traitement des eaux usées*, visitez le site Web du Fonds de durabilité des Grands Lacs à l'adresse http://sustainabilityfund.gc.ca ou communiquez avec le Gestionnaire, Fonds de durabilité des Grands Lacs, 867, chemin Lakeshore, Burlington (Ontario) L7R 4A6, (905) 336-6273.

Pour obtenir une copie de la *Loi sur les pêches*, visitez le site Web suivant : http://lois.justice.gc.ca/fr/F-14. Pour obtenir plus d'information sur les politiques de conformité et d'application des dispositions de la *Loi sur les pêches* et de la *Loi canadienne sur la protection de l'environnement (1999)*, visitez le site Web de l'application des lois sur l'environnement à l'adresse www.ec.gc.ca/ele-ale/policies/policies_f.asp.

De l'information supplémentaire sur la prévention de la pollution et la préparation de plans de la prévention de la pollution est disponible sur le site Web du Bureau national de la prévention de la pollution (www.ec.gc.ca/nopp) et sur celui du Centre canadien d'information sur la prévention de la pollution (www.ec.gc.ca/cppic), ainsi qu'aux bureaux régionaux d'Environnement Canada.

Pour obtenir de l'information concernant la stratégie pancanadienne du CCME sur la gestion des effluents d'eaux usées municipales, visitez le site Web du CCME à l'adresse www.ccme.ca/initiatives/water.fr.html?category_id=81.

16. Code de référence

À des fins administratives, toutes les communications adressées à Environnement Canada au sujet de cet avis doivent mentionner le code de référence suivant : P2CLMWWE.

17. Déclarations et formulaires

Les déclarations et les formulaires dont il est question dans cet avis sont disponibles, et devront être soumis, à l'adresse suivante :

Bureau national de la prévention de la pollution
Division de l'innovation et de la mise en œuvre de la LCPE
Environnement Canada
351, boulevard Saint-Joseph, 13^e étage
Gatineau (Québec) K1A 0H3

De plus, les formulaires peuvent être remplis électroniquement sur le site Internet mentionné ci-dessous.

Electronic copies of this Notice and the instructions for completing the declarations and forms (Schedules 1 to 5) are available from the National Office of Pollution Prevention Web site, at www.ec.gc.ca/nopp/p2p/en/p2notices.cfm or can be requested by telephone at (819) 994-0186, by facsimile at (819) 953-7970, or by electronic mail at cepap2plans@ec.gc.ca.

The Minister of the Environment intends to publish, in part, the information submitted in response to this Notice on Environment Canada's Green Lane Web site. All persons submitting information to the Minister are entitled to submit a request under section 313 of the Act that specific information be treated as confidential.

18. Environment Canada contact information

For residents of Newfoundland and Labrador

Environmental Protection Branch – Atlantic Region
Environment Canada
6 Bruce Street
Mount Pearl, Newfoundland and Labrador A1N 4T3
Telephone: (709) 772-5491
Facsimile: (709) 772-5097

For residents of Prince Edward Island

Environmental Protection Branch – Atlantic Region
Environment Canada
97 Queen Street, Room 202
Charlottetown, Prince Edward Island C1A 4A9
Telephone: (902) 566-7043
Facsimile: (902) 566-7279

For residents of Nova Scotia

Environmental Protection Branch – Atlantic Region
Environment Canada
Queen Square, 16th Floor
45 Alderney Drive
Dartmouth, Nova Scotia B2Y 2N6
Telephone: (902) 426-8926
Facsimile: (902) 426-3897

For residents of New Brunswick

Environmental Protection Branch – Atlantic Region
Environment Canada
77 Westmorland Street, Suite 450
Fredericton, New Brunswick E3B 6Z3
Telephone: (506) 452-3286
Facsimile: (506) 452-3003

For residents of Quebec

Environmental Protection Branch – Quebec Region
Environment Canada
105 McGill Street, 4th Floor
Montréal, Quebec H2Y 2E7
Telephone: (514) 283-4670
Facsimile: (514) 283-4423

For residents of Ontario

Environmental Protection Branch – Ontario Region
Environment Canada
4905 Dufferin Street
Downsview, Ontario M3H 5T4
Telephone: (416) 739-5888
Facsimile: (416) 739-4342

Une copie électronique de cet avis ainsi que les directives nécessaires pour remplir les déclarations et les formulaires (annexes 1 à 5) sont disponibles sur le site Web du Bureau national de la prévention de la pollution à l'adresse www.ec.gc.ca/nopp/p2p/FR/p2notices.cfm ou peuvent être obtenues par téléphone au (819) 994-0186, par télécopieur au (819) 953-7970, ou par courriel à l'adresse cepap2plans@ec.gc.ca.

Le ministre de l'Environnement a l'intention de publier, en partie, les informations présentées en réponse à cet avis sur le site Web de la Voie verte d'Environnement Canada. Toute personne présentant des informations au ministre peut soumettre une demande en vertu de l'article 313 de la Loi, afin que certaines informations spécifiques soient traitées de façon confidentielle.

18. Bureaux d'information d'Environnement Canada

Pour les résidents de Terre-Neuve-et-Labrador

Direction de la protection de l'environnement — Région de l'Atlantique
Environnement Canada
6, rue Bruce
Mount Pearl (Terre-Neuve-et-Labrador) A1N 4T3
Téléphone : (709) 772-5491
Télécopieur : (709) 772-5097

Pour les résidents de l'Île-du-Prince-Édouard

Direction de la protection de l'environnement — Région de l'Atlantique
Environnement Canada
97, rue Queen, Pièce 202
Charlottetown (Île-du-Prince-Édouard) C1A 4A9
Téléphone : (902) 566-7043
Télécopieur : (902) 566-7279

Pour les résidents de la Nouvelle-Écosse

Direction de la protection de l'environnement — Région de l'Atlantique
Environnement Canada
Queen Square, 16^e étage
45, promenade Alderney
Dartmouth (Nouvelle-Écosse) B2Y 2N6
Téléphone : (902) 426-8926
Télécopieur : (902) 426-3897

Pour les résidents du Nouveau-Brunswick

Direction de la protection de l'environnement — Région de l'Atlantique
Environnement Canada
77, rue Westmorland, Bureau 450
Fredericton (Nouveau-Brunswick) E3B 6Z3
Téléphone : (506) 452-3286
Télécopieur : (506) 452-3003

Pour les résidents du Québec

Direction de la protection de l'environnement — Région du Québec
Environnement Canada
105, rue McGill, 4^e étage
Montréal (Québec) H2Y 2E7
Téléphone : (514) 283-4670
Télécopieur : (514) 283-4423

Pour les résidents de l'Ontario

Direction de la protection de l'environnement — Région de l'Ontario
Environnement Canada
4905, rue Dufferin
Downsview (Ontario) M3H 5T4
Téléphone : (416) 739-5888
Télécopieur : (416) 739-4342

For residents of Manitoba

Environmental Protection Branch – Prairie and Northern Region
Environment Canada
123 Main Street
Winnipeg, Manitoba R3C 4W2
Telephone: (204) 983-4811
Facsimile: (204) 983-0960

For residents of Saskatchewan

Environmental Protection Branch – Prairie and Northern Region
Environment Canada
300-2365 Albert Street
Regina, Saskatchewan S4P 4K1
Telephone: (306) 780-6390
Facsimile: (306) 780-6466

For residents of Alberta

Environmental Protection Branch – Prairie and Northern Region
Environment Canada
4999 98th Avenue
Edmonton, Alberta T6B 2X3
Telephone: (780) 951-8860
Facsimile: (780) 495-4099

For residents of the Northwest Territories and Nunavut

Environmental Protection Branch – Prairie and Northern Region
Environment Canada
301-5204 50th Avenue
Yellowknife, Northwest Territories X1A 1E2
Telephone: (867) 669-4725
Facsimile: (867) 873-8185

For residents of British Columbia

Environmental Protection Branch – Pacific and Yukon Region
Environment Canada
201-401 Burrard Street
Vancouver, British Columbia V6C 3S5
Telephone: (604) 666-2799
Facsimile: (604) 666-9107

For residents of Yukon

Environmental Protection Branch – Pacific and Yukon Region
Environment Canada
91782 Alaska Highway
Whitehorse, Yukon Territory Y1A 5B7
Telephone: (867) 667-3401
Facsimile: (867) 667-7962

Environment Canada Headquarters

Environmental Technology Advancement Directorate
Environmental Protection Service
Place Vincent Massey
351 Saint-Joseph Boulevard
Gatineau, Quebec K1A 0H3
Telephone: (819) 953-8074
Facsimile: (819) 953-7253

Pour les résidents du Manitoba

Direction de la protection de l'environnement — Région des Prairies et du Nord
Environnement Canada
123, rue Main
Winnipeg (Manitoba) R3C 4W2
Téléphone : (204) 983-4811
Télécopieur : (204) 983-0960

Pour les résidents de la Saskatchewan

Direction de la protection de l'environnement — Région des Prairies et du Nord
Environnement Canada
2365, rue Albert, Bureau 300
Regina (Saskatchewan) S4P 4K1
Téléphone : (306) 780-6390
Télécopieur : (306) 780-6466

Pour les résidents de l'Alberta

Direction de la protection de l'environnement — Région des Prairies et du Nord
Environnement Canada
4999 98th Avenue
Edmonton (Alberta) T6B 2X3
Téléphone : (780) 951-8860
Télécopieur : (780) 495-4099

Pour les résidents des Territoires du Nord-Ouest et du Nunavut

Direction de la protection de l'environnement — Région des Prairies et du Nord
Environnement Canada
5204 50th Avenue, Bureau 301
Yellowknife (Territoires du Nord-Ouest) X1A 1E2
Téléphone : (867) 669-4725
Télécopieur : (867) 873-8185

Pour les résidents de la Colombie-Britannique

Direction de la protection de l'environnement — Région du Pacifique et du Yukon
Environnement Canada
401, rue Burrard, Bureau 201
Vancouver (Colombie-Britannique) V6C 3S5
Téléphone : (604) 666-2799
Télécopieur : (604) 666-9107

Pour les résidents du Yukon

Direction de la protection de l'environnement — Région du Pacifique et du Yukon
Environnement Canada
91782, route de l'Alaska
Whitehorse (Territoire du Yukon) Y1A 5B7
Téléphone : (867) 667-3401
Télécopieur : (867) 667-7962

Bureau national d'Environnement Canada

Direction générale pour l'avancement de la technologie environnementale
Service de la protection de l'environnement
Place-Vincent-Massey
351, boulevard Saint-Joseph
Gatineau (Québec) K1A 0H3
Téléphone : (819) 953-8074
Télécopieur : (819) 953-7253

EXPLANATORY NOTE

(*This note is not part of the Notice.*)

Compliance

Compliance with the Act is mandatory under subsection 272(1) of the Act. Subsection 272(2) of the Act defines the penalties for persons who commit offenses under the Act. Subsections 273(1) and 273(2) further outline the terms and penalties of those persons providing false or misleading information. Penalties under subsections 272(2) and 273(2) include fines of not more than $1,000,000, imprisonment for a term of not more than three years, or both.

For additional information on the Act and the *Compliance and Enforcement Policy for the Canadian Environmental Protection Act, 1999* and on applicable penalties, please contact the Enforcement Branch at (819) 953-0331. The Policy is available at www.ec.gc.ca/ceparegistry/enforcement.

NOTE EXPLICATIVE

(*Cette note ne fait pas partie de l'avis.*)

Conformité

En vertu du paragraphe 272(1), la conformité à la Loi est obligatoire. Le paragraphe 272(2) de la Loi détermine les peines applicables pour quiconque commet une infraction en vertu de la Loi. De plus, les paragraphes 273(1) et 273(2) déterminent les peines applicables à quiconque communique des renseignements faux ou trompeurs. Les paragraphes 272(2) et 273(2) édictent qu'une amende maximale d'un million de dollars et un emprisonnement maximal de trois ans, ou que l'une de ces peines, peuvent être imposés.

Pour tout renseignement additionnel sur la LCPE (1999), la *Politique d'application de la Loi canadienne sur la protection de l'environnement (1999)* et les peines applicables, veuillez communiquer avec la Direction de l'application de la loi au (819) 953-0331. La politique est disponible sur Internet à l'adresse suivante : www.ec.gc.ca/RegistreLCPE/enforcement.

Note: Please contact the National Office of Pollution Prevention for more information about electronic reporting or the filing of paper forms.

Schedule 1: Declaration That a Pollution Prevention Plan Has Been Prepared and Is Being Implemented – Inorganic Chloramines and Chlorinated Wastewater Effluents (Subsection 58(1) of CEPA 1999)

Notice Reference Code: P2CLMWWE

Please refer to the instruction booklet "Instructions for Completing the Schedules of the *Canada Gazette* Notice Requiring the Preparation and Implementation of Pollution Prevention Plans for Inorganic Chloramines and Chlorinated Wastewater Effluents" for guidance on how to complete this Declaration.

Electronic copies of the Notice, and the instructions for completing the declarations (Schedules 1 to 5), are available from the National Office of Pollution Prevention Web site at www.ec.gc.ca/nopp/p2p/en/p2notices.cfm or can be requested by telephone at (819) 994-0186, by facsimile at (819) 953-7970, or by e-mail at CEPAP2Plans@ec.gc.ca.

Is this an amendment to a Declaration previously submitted? ☐ Yes ☐ No

If yes, complete Parts 1.0 and 9.0 and any other Parts of this Declaration where previously reported information has become false or misleading. Previously reported information that is unchanged need not be resubmitted.

1.0 Information on the Person or Class of Persons Subject to the Notice

Name of the Person or Class of Persons Subject to the Notice: ____________

Facility Name: ____________

Street Address of Facility: ____________

City: ____________ Province/Territory: ____________ Postal Code: ____________

Telephone Number: (with area code) ____________ E-mail (if available): ____________

If different from Street Address Mailing Address of Facility: ____________

City: ____________ Province/Territory: ____________ Postal Code: ____________

National Pollutant Release Inventory ID (if no ID, leave blank): ____________

Six-digit North American Industry Classification System (NAICS) Code: 221320

Facility Technical Contact: ____________

E-mail (if available): ____________

Telephone Number: (with area code) ____________ Fax Number (if available): (with area code) ____________

2.0 Use of Plans Prepared or Implemented for Another Purpose

Is the pollution prevention plan used to fulfill the obligations of the Notice

- a pollution prevention plan that was previously prepared on a voluntary basis? ☐ Yes ☐ No
- a pollution prevention plan that was previously prepared for another government or under another Act of Parliament? ☐ Yes ☐ No

If yes, identify the other government requirement(s) or Act(s) of Parliament.

3.0 Substance and Activity

Substance and Activity for which information is required

Inorganic Chloramines and Chlorinated Wastewater Effluents: Persons identified in section 2 of the Notice who are required to prepare and implement a pollution prevention plan for inorganic chloramines and chlorinated wastewater effluents for the use of chlorine or chlorine compounds in wastewater systems and the release of chlorinated wastewater effluent to surface water.

4.0 Baseline Information Prior to Implementation of the Pollution Prevention (P2) Plan

This Declaration requires reporting of data from the Preparation Year, either **2004** or **2005** (January 1 to December 31).

If the person(s) subject to the Notice has been granted a time extension to prepare a plan that requires reporting for a year other than **2004** or **2005**, all references to **2004** or **2005** in this Declaration are considered to represent the new Preparation Year for which the person(s) is(are) required to report.

If applicable, indicate the new Preparation Year for which the person(s) is(are) reporting: ______

4.1 - 4.4 No information required for Parts 4.1 to 4.4 of this Declaration

4.5 Additional Baseline Information

4.5.1 Wastewater System Information

This section requires reporting of information on the wastewater system in place for 2004 or 2005. Check whichever of the following boxes apply to your system. Note that more than one box in each section may apply.

No Treatment

☐ No Treatment (e.g. collection system with release to surface water)

Preliminary Treatment

☐ None
☐ Grit Removal
☐ Screening
☐ Skimming
☐ Other (describe) ______

Physical/Chemical Primary Treatment

☐ None
☐ Primary Sedimentation/Clarification
☐ Chemical Flocculation
☐ Other (describe) ______

Biological or Secondary Treatment – Mechanical Systems (some systems may have more than one kind of treatment)

☐ None
☐ Conventional Activated Sludge
☐ Extended Aeration Activated Sludge
☐ Pure Oxygen Activated Sludge
☐ Other Activated Sludge
☐ Oxidation Ditch
☐ Trickling Filter
☐ Rotating Biological Contactor (RBC)
☐ Sequencing Batch Reactor (SBR)
☐ Other (describe) ______

Biological or Secondary Treatment – Lagoons or Waste Stabilization Ponds (WSPs) (some systems may have more than one kind of treatment)

☐ None
☐ Aerated
☐ Aerobic
☐ Facultative
☐ Storage Ponds
☐ Anaerobic
☐ Other (describe) ______

Advanced or Tertiary Treatment

☐ None
☐ Polishing Ponds
☐ Ammonia Stripping or Air Stripping
☐ Biological Nutrient Removal (Nitrogen and Phosphorus)
☐ Biological Ammonia Removal – Nitrification Only (NH_3 -> NO_3)
☐ Biological Nitrogen Removal – Nitrification and Denitrification (NH_3 -> N_2)
☐ Biological Phosphorus Removal
☐ Chemical Precipitation (Phosphorus)
☐ Filtration
☐ Other (describe) ______________________________

Effluent Disinfection

☐ None
☐ Disinfection: All Year
☐ Disinfection: Seasonal or intermittent. If seasonal, specify the period of disinfection (which months) or if it is intermittent, specify the frequency: ________ ____
☐ Chlorination Only
☐ Chlorination and Dechlorination
☐ Ozone
☐ Ultraviolet Irradiation
☐ Other (describe) ______________________________

Other Information

Name of the surface water body that effluent is released to ________________________ ☐ Freshwater ☐ Saltwater

4.5.2 Releases to Surface Water

4.5.2.1 *Inorganic Chloramines and Chlorinated Wastewater Effluents*

Report in the table below the average flow of wastewater effluent and the maximum Total Residual Chlorine (TRC) concentrations. The average monthly flow should be determined on the basis of daily flow measurements. The maximum total residual chlorine concentration should be determined on the basis of representative sampling.

Preparation Year ________ **(Month)**	**Average Flow of Effluent (m^3/day)**	**Maximum Total Residual Chlorine (TRC) concentration (mg/L as Cl^-)**
January		
February		
March		
April		
May		
June		
July		
August		
September		
October		
November		
December		

5.0 Anticipated Actions and Results

5.1 Anticipated Action(s)

The following section (Parts 5.1.1 through 5.1.6) must be completed separately for each anticipated action in the pollution prevention plan, i.e. this section will be completed as many times as there are anticipated actions to report.

In Part 5.1.1, describe for the activity identified in Part 3.0 of this Declaration the anticipated action to be taken in implementing the Pollution Prevention Plan. In Parts 5.1.2 and 5.1.3, for each anticipated action, identify the type of pollution prevention method(s) or environmental protection method(s), by selecting from the list of options provided below. In Part 5.1.4, report, where possible, the corresponding change to the maximum concentration of total residual chlorine measured in the effluent released to surface water, anticipated to be achieved from implementation of that action, in mg/L. Refer to the instructions for specific information on how to report. Indicate a decrease with a negative sign ("–") and an increase with a positive sign ("+") in front of the reported change. Note that predicting a quantitative change as a result of some anticipated actions, such as training, may not be possible. Finally, in Part 5.1.6, identify the planned completion date for the anticipated action.

5.1.1 Anticipated Action: ____

5.1.2 Type of Pollution Prevention Method(s):

☐ Equipment or process modifications

☐ Spill and leak prevention

☐ On-site reuse, recycling or recovery

☐ Good operating practices or training

☐ Other: ____________________

5.1.3 Other Type of Environmental Protection Method(s):

☐ Energy recovery

☐ Off-site recycling

☐ Waste treatment

☐ Pollution control

☐ Disposal

☐ Other: ____________________

5.1.4 Anticipated Change(s): ____________________

5.1.5 *No information required for Part 5.1.5 of this Declaration*

5.1.6 Planned Completion Date (year/month/day): ____________________

This ends the section (Parts 5.1.1 through 5.1.6) that must be completed separately for each anticipated action in the P2 plan.

5.2 No information required for Part 5.2

5.3 Detailed Anticipated Results Information

Total Anticipated Results for Inorganic Chloramines and Chlorinated Wastewater Effluents

The table below summarizes, for the activity identified in Part 3.0 of this Declaration, the anticipated change to the maximum concentration of total residual chlorine (TRC) in the effluent released to surface water, in mg/L and as a percentage relative to the Preparation Year.

Report the total changes anticipated to be achieved from implementing all of the anticipated actions described in Part 5.1 of this Declaration.

Maximum Concentration of TRC in the Preparation Year (mg/L)	Anticipated Maximum Concentration of TRC in the Implementation Year (mg/L)	Anticipated Change* in Maximum Concentration (%)

* Indicate a decrease with a negative sign ("−") and an increase with a positive sign ("+") in front of the reported change.

6.0 Monitoring and Reporting

For the activity identified in Part 3.0 of this Declaration, describe anticipated monitoring and reporting that will be used to track progress in implementing the Pollution Prevention Plan.

7.0 Risk Management Objective

For the activity identified in Part 3.0 of this Declaration, describe how the Pollution Prevention Plan outlined in this Declaration meets the risk management objective identified in subsection 4(3) of the Notice. If this plan does not meet the risk management objective, explain why.

8.0 Factors to Consider

Describe what was done by the person or class of persons subject to the Notice to take into account the other "factors to consider" in subsections 4.2 and 4.5 of the Notice, except those factors for which a waiver has been granted by the Minister.

9.0 Certification

I hereby certify that a Pollution Prevention Plan has been prepared and is being implemented for inorganic chloramines and chlorinated wastewater effluents and that the information provided in this Declaration is true, accurate and complete.

____________________ ____________________

Signature of the Person(s) Subject to the Notice or
Duly Authorized Representative

Date

Name: ____________________
Please Print

Title/Position: ____________________
Please Print

Note : Veuillez communiquer avec le Bureau national de la prévention de la pollution pour obtenir plus d'information au sujet de la soumission électronique ou du dépôt des formulaires écrits.

Annexe 1 : Déclaration confirmant qu'un plan de prévention de la pollution a été élaboré et qu'il est en cours d'exécution — chloramines inorganiques et eaux usées chlorées [paragraphe 58(1) de la LCPE (1999)]

Code de référence de l'avis : **P2CLMWWE**

Pour plus d'information sur la façon de remplir cette déclaration, consulter la brochure « Directives pour remplir les annexes de l'avis de la *Gazette du Canada* requérant l'élaboration et l'exécution de plans de prévention de la pollution pour les chloramines inorganiques et les eaux usées chlorées ».

Une copie électronique de cet avis et les instructions pour remplir les déclarations (annexes 1 à 5) sont disponibles sur le site Web du Bureau national de la prévention de la pollution à l'adresse www.ec.gc.ca/nopp/p2p/FR/p2notices.cfm ou peuvent être obtenues par téléphone au (819) 994-0186, par télécopieur au (819) 953-7970, ou par courriel à l'adresse cepap2plans@ec.gc.ca.

La présente déclaration sert-elle à apporter une modification à une déclaration déjà déposée? ☐ Oui ☐ Non

Si vous avez coché « oui », remplissez les parties 1.0 et 9.0, ainsi que toute autre partie de cette déclaration pour laquelle des renseignements déjà déclarés sont maintenant faux ou trompeurs. Il n'est pas nécessaire de répéter les informations inchangées.

1.0 Renseignements sur la(les) personne(s) ou catégorie de personnes visée(s) par l'avis

Nom de la(des) personne(s) ou catégorie de personnes visée(s) par l'avis : ______

Nom de l'installation : ______

Adresse civique de l'installation : ______

Ville : ______ Province/Territoire : ______ Code postal : ______

Téléphone : ______ Courriel (si disponible) : ______
(indicatif régional)

Adresse postale de l'installation,
si différente de l'adresse civique : ______

Ville : ______ Province/Territoire : ______ Code postal : ______

Numéro d'identité de l'Inventaire national des rejets de polluants (si aucun, laissez en blanc) : ______

Code à six chiffres du Système de classification des industries de l'Amérique du Nord (SCIAN) : 221320

Responsable des renseignements techniques : ______

Courriel (si disponible) : ______

Téléphone : ______ Télécopieur (si disponible) : ______
(y compris l'indicatif régional) (y compris l'indicatif régional)

2.0 Utilisation de plans déjà élaborés ou exécutés à d'autres fins

Le plan de prévention de la pollution utilisé pour satisfaire aux exigences de l'avis a-t-il :

- été préparé à titre volontaire? ☐ Oui ☐ Non
- été préparé pour un autre gouvernement ou en vertu d'une autre loi fédérale? ☐ Oui ☐ Non

Si vous avez coché « oui », indiquez la ou les exigences de cet autre gouvernement ou de cette(ces) autre(s) loi(s) fédérale(s).

3.0 Substance et activité

Substance et activité pour lesquelles des informations sont requises

Chloramines inorganiques et eaux usées chlorées : Personnes identifiées dans l'article 2 de l'avis, qui doivent élaborer et exécuter un plan de prévention de la pollution pour les chloramines inorganiques et les eaux usées chlorées liées à l'usage du chlore ou de composés chlorés dans les réseaux d'assainissement et le rejet d'eaux usées chlorées dans les eaux de surface.

4.0 Information de base antérieure à l'exécution du plan de prévention de la pollution (P2)

Cette déclaration requiert la présentation des données pour l'année de préparation, soit **2004** ou **2005** (du 1er janvier au 31 décembre).

Si la(les) personne(s) visée(s) par l'avis a(ont) obtenu une prorogation de délai pour préparer un plan qui requiert la présentation de données pour une année autre que **2004** ou **2005**, toutes les références aux années **2004** ou **2005** dans la présente déclaration doivent être considérées comme renvoyant à la nouvelle année de préparation pour laquelle la(les) personne(s) doit(doivent) faire rapport.

Le cas échéant, veuillez indiquer la nouvelle année de préparation pour laquelle la(les) personne(s) visée(s) par l'avis doit(doivent) soumettre un rapport : ____________________

4.1 - 4.4 Aucune information requise pour les parties 4.1 à 4.4 de cette déclaration

4.5 Information de base additionnelle

4.5.1 Information sur le réseau d'assainissement

Cette section requiert de l'information au sujet du réseau d'assainissement en place pour 2004 ou 2005. Cochez toutes les cases suivantes qui s'appliquent à votre réseau. Notez que plus d'une case par section peuvent s'appliquer.

Aucun traitement

☐ Aucun traitement (par exemple, système de collecte avec déversement dans une eau de surface)

Traitement préliminaire

☐ Aucun
☐ Dessablage
☐ Tamis/grilles à barreaux
☐ Écrémage
☐ Autre (préciser) ____________________

Traitement primaire physique/chimique

☐ Aucun
☐ Décantation primaire/clarification
☐ Floculation chimique
☐ Autre (préciser) ____________________

Traitement secondaire ou biologique — systèmes mécaniques (certains systèmes peuvent avoir plus d'un type de traitement)

☐ Aucun
☐ Boues activées conventionnelles
☐ Boues activées par aération prolongée
☐ Boues activées par oxygène pur
☐ Autres boues activées
☐ Fossé d'oxydation
☐ Réacteur à lit fixe ou à lit bactérien aéré
☐ Disques biologiques
☐ Réacteur continu
☐ Autre (préciser) ____________________

Traitement secondaire ou biologique — étangs ou bassins de stabilisation (certains systèmes peuvent avoir plus d'un type de traitement)

☐ Aucun
☐ Aéré
☐ Aérobique
☐ Facultatif
☐ Étangs de stockage
☐ Anaérobique
☐ Autre (préciser) ____________________

Traitement tertiaire ou additionnel

☐ Aucun
☐ Bassins ou étangs de polissage
☐ Stripage de l'ammoniac ou stripage à l'air
☐ Élimination biologique des nutriments (azote et phosphore)
☐ Élimination biologique de l'ammoniac — Nitrification seulement (NH_3 -> NO_3)
☐ Élimination biologique de l'azote — Nitrification et dénitrification (NH_3 -> N_2)
☐ Élimination biologique du phosphore
☐ Précipitation chimique (phosphore)
☐ Filtration
☐ Autre (préciser) ____________________

Désinfection des effluents

☐ Aucun
☐ Désinfection : continue à l'année
☐ Désinfection : saisonnière ou intermittente. Si saisonnière, préciser la période de désinfection (quels mois) ou si intermittente, préciser la fréquence : ____________________
☐ Chloration seulement
☐ Chloration et déchloration
☐ Ozone
☐ Irradiation par ultraviolets
☐ Autre (préciser) ____________________

Autre information

Nom du cours d'eau où l'effluent est déversé ____________________ ☐ Eau douce ☐ Eau salée

4.5.2 Rejets à l'eau de surface

4.5.2.1 Chloramines inorganiques et eaux usées chlorées

Déclarez dans le tableau ci-dessous le débit moyen de l'effluent d'eaux usées et les concentrations maximales de chlore résiduel total (CRT). Le débit moyen mensuel devrait être calculé en fonction des mesures du débit quotidien. La concentration maximale de chlore résiduel total devrait être déterminée en fonction d'un échantillon représentatif.

Année de préparation ______ **Mois**	**Débit moyen de l'effluent (m^3/jour)**	**Concentration maximale de chlore résiduel total (CRT) (mg/L en Cl^-)**
Janvier		
Février		
Mars		
Avril		
Mai		
Juin		
Juillet		
Août		
Septembre		
Octobre		
Novembre		
Décembre		

5.0 Mesures et résultats prévus

5.1 *Mesure(s) prévue(s)*

Les parties suivantes de la présente déclaration (parties 5.1.1 à 5.1.6) doivent être remplies séparément pour chaque mesure prévue indiquée dans le plan de prévention de la pollution, c'est-à-dire que cette section doit être remplie autant de fois qu'il y a de mesures à déclarer.

Dans la partie 5.1.1, décrivez, pour l'activité identifiée à la partie 3.0 de la présente déclaration, la mesure prévue pour l'exécution du plan de prévention de la pollution. Dans les parties 5.1.2 et 5.1.3, identifiez le type de mesures de prévention de la pollution ou de protection de l'environnement, en choisissant l'une des options fournies ci-dessous. Dans la partie 5.1.4, inscrivez, le cas échéant, le changement prévu à la concentration maximale de chlore résiduel total mesurée dans l'effluent rejeté à l'eau de surface, en mg/L, provenant de la mise en œuvre de la mesure. Pour obtenir des informations spécifiques sur la façon de compléter cette section, référez-vous aux instructions. Indiquez une diminution par le signe « − » et une augmentation par le signe « + » devant la quantité indiquée. Notez que dans certains cas, il peut s'avérer impossible de prévoir un changement quantitatif pour certaines mesures prévues, comme dans le cas de la formation du personnel. Enfin, dans la partie 5.1.6, indiquez la date d'achèvement prévue pour chaque mesure prévue.

5.1.1 Mesure prévue : ______________________________

5.1.2 Types de méthodes de prévention de la pollution :

☐ Modifications de l'équipement ou du procédé
☐ Prévention des fuites ou des déversements
☐ Récupération, réutilisation ou recyclage sur place
☐ Bonnes pratiques d'exploitation ou formation
☐ Autres : ______________________________

5.1.3 Autres types de méthodes de protection de l'environnement :

☐ Récupération d'énergie
☐ Recyclage hors site
☐ Traitement des déchets
☐ Contrôle de la pollution
☐ Élimination
☐ Autres : ______________________________

5.1.4 Changement(s) prévu(s) : ______________________________

5.1.5 *Aucune information n'est requise pour la partie 5.1.5 de cette déclaration*

5.1.6 Date d'achèvement prévue (année/mois/jour) : ______________________________

Ceci termine les parties 5.1.1 à 5.1.6 devant être remplies séparément pour chaque mesure prévue dans le plan de prévention de la pollution.

5.2 Aucune information n'est requise pour la partie 5.2 de cette déclaration

5.3 Information détaillée sur les résultats prévus

Résultats totaux prévus pour les chloramines inorganiques et les eaux usées chlorées

Le tableau ci-dessous résume, pour l'activité identifiée dans la partie 3.0 de cette déclaration, le changement total prévu à la concentration maximale de chlore résiduel total (CRT) dans l'effluent rejeté à l'eau de surface, en mg/L et en pourcentage par rapport à l'année de préparation.

Déclarez le changement total prévu à la suite de la mise en œuvre des mesures prévues décrites dans la partie 5.1 de cette déclaration.

Concentration maximale de CRT dans l'année de préparation (mg/L)	**Concentration maximale de CRT prévue dans l'année de la mise en œuvre (mg/L)**	**Changement* prévu à la concentration maximale (%)**

* Indiquez une diminution avec un signe négatif (« – ») et une augmentation avec un signe positif (« + ») devant la quantité déclarée.

6.0 Surveillance et rapport

Pour l'activité identifiée à la partie 3.0 de cette déclaration, décrivez les méthodes de surveillance et de compte rendu qui seront utilisées pour suivre les progrès de l'exécution du plan de prévention de la pollution.

7.0 Objectif de gestion du risque

Décrivez comment le plan de prévention de la pollution, tel qu'il est décrit dans cette déclaration, répond à l'objectif de gestion du risque décrit au paragraphe 4(3) de l'avis pour l'activité identifiée à la partie 3.0 de cette déclaration. Si ce plan ne répond pas à l'objectif de gestion du risque, expliquez pourquoi.

8.0 Facteurs à prendre en considération

Décrivez les mesures prises par les personnes ou catégories de personnes assujetties à l'avis pour tenir compte des « facteurs à prendre en considération » des paragraphes 4.2 et 4.5 de l'avis, sauf pour les facteurs pour lesquels une demande de dérogation a été accordée par le ministre.

9.0 Certification

J'atteste qu'un plan de prévention de la pollution a été élaboré pour les chloramines inorganiques et les eaux usées chlorées et qu'il est en cours d'exécution, et que les renseignements soumis dans la présente déclaration sont véridiques, exacts et complets.

______________________________ ______________________________

Signature de la(des) personne(s) visée(s) par l'avis ou représentant(e) autorisé(e) Date

Nom : ______________________________

En lettres moulées s.v.p.

Titre/Poste : ______________________________

En lettres moulées s.v.p.

Note: Please contact the National Office of Pollution Prevention for more information about electronic reporting or the filing of paper forms.

Schedule 2: Request for Waiver of the Requirement to Consider a Factor or Factors – Inorganic Chloramines and Chlorinated Wastewater Effluents (Subsection 56(5) of CEPA 1999)

Notice Reference Code: P2CLMWWE

Please refer to the instruction booklet "Instructions for Completing the Schedules of the *Canada Gazette* Notice Requiring the Preparation and Implementation of Pollution Prevention Plans for Inorganic Chloramines and Chlorinated Wastewater Effluents" for guidance on how to complete this Request.

Electronic copies of the Notice, and the instructions for completing the declarations (Schedules 1 to 5), are available from the National Office of Pollution Prevention Web site at www.ec.gc.ca/nopp/p2p/en/p2notices.cfm or can be requested by telephone at (819) 994-0186, by facsimile at (819) 953-7970 or by e-mail at CEPAP2Plans@ec.gc.ca.

1.0 Information on the Person or Class of Persons Subject to the Notice

Name of the Person or Class of Persons Subject to the Notice: ______________________________

Facility Name: ______________________________

Street Address of Facility: ______________________________

City: _______________ Province/Territory: _______________ Postal Code: _______________

Telephone Number: ______________________ E-mail (if available): ______________________
(with area code)

If different from Street Address
Mailing Address of Facility: ______________________

City: ____________ Province/Territory: ____________ Postal Code: ____________

National Pollutant Release Inventory ID (if no ID, leave blank): ____________

Six-digit North American Industry Classification System (NAICS) Code: 221320

Facility Technical Contact: ______________________

E-mail (if available): ______________________

Telephone Number: ______________________ Fax Number (if available): ______________________
(with area code) (with area code)

2.0 Factor(s) for which a Waiver is Requested

Identify exactly for which factor(s) listed in the Notice a waiver is requested.

3.0 Rationale for Request

Explain why it would not be reasonable or practicable to consider each factor for which a waiver is requested.

Explain how the outcome of the P2 plan will be affected if this(these) "factor to consider" is(are) not taken into account.

Explain which, if any, additional factor(s) you propose to consider in preparing the pollution prevention plan (optional).

4.0 Certification

I hereby certify that the information provided in this Request is true, accurate and complete.

______________________ ______________________
Signature of the Person(s) Subject to the Notice or Duly Authorized Representative Date

Name: ______________________
Please Print

Title/Position: ______________________
Please Print

Note : Veuillez communiquer avec le Bureau national de la prévention de la pollution pour obtenir plus d'information au sujet de la soumission électronique ou du dépôt des formulaires écrits.

Annexe 2 : Demande de dérogation à l'obligation de prendre en considération certains facteurs — Chloramines inorganiques et eaux usées chlorées [paragraphe 56(5) de la LCPE (1999)]

Code de référence de l'avis : P2CLMWWE

Pour plus d'information sur la façon de remplir cette déclaration, consulter la brochure « Directives pour remplir les annexes de l'avis de la *Gazette du Canada* requérant l'élaboration et l'exécution de plans de prévention de la pollution pour les chloramines inorganiques et les eaux usées chlorées ».

Une copie électronique de cet avis et les instructions pour remplir les déclarations (annexes 1 à 5) sont disponibles sur le site Web du Bureau national de la prévention de la pollution à l'adresse www.ec.gc.ca/nopp/p2p/FR/p2notices.cfm ou peuvent être obtenues par téléphone au (819) 994-0186, par télécopieur au (819) 953-7970 ou par courriel à l'adresse cepap2plans@ec.gc.ca.

1.0 Renseignements sur la(les) personne(s) ou catégorie de personnes visée(s) par l'avis

Nom de la(des) personne(s) ou catégorie de personnes visée(s) par l'avis : ____________________

Nom de l'installation : ____________________

Adresse civique de l'installation : ____________________

Ville : ____________ Province/Territoire : ____________ Code postal : ____________

Téléphone : ____________ Courriel (si disponible) : ____________
(y compris l'indicatif régional)

Adresse postale de l'installation, si différente de l'adresse civique : ____________________

Ville : ____________ Province/Territoire : ____________ Code postal : ____________

Numéro d'identité de l'Inventaire national des rejets de polluants (si aucun, laissez en blanc) : ____________

Code à six chiffres du Système de classification des industries de l'Amérique du Nord (SCIAN) : 221320

Responsable des renseignements techniques : ____________________

Courriel (si disponible) : ____________________

Téléphone : ____________ Télécopieur (si disponible) : ____________
(y compris l'indicatif régional) (y compris l'indicatif régional)

2.0 Facteur(s) faisant l'objet d'une demande de dérogation

Indiquez de façon précise pour quel(s) facteur(s) énuméré(s) dans cet avis une dérogation est demandée.

3.0 Justification de la demande

Expliquez pourquoi il serait déraisonnable ou impossible de prendre en considération chacun des facteurs pour lesquels une dérogation est demandée.

Expliquez comment les résultats du plan de prévention de la pollution seront affectés si ce(ces) « facteur(s) à prendre en considération » n'est(ne sont) pas considéré(s).

Si vous proposez d'utiliser un ou des facteurs additionnels lors de l'élaboration du plan de prévention de la pollution, expliquez lequel ou lesquels (optionnel).

4.0 Certification

Par la présente, j'atteste que l'information dans cette demande est véridique, exacte et complète.

____________________ ____________________
Signature de la(des) personne(s) visée(s) par l'avis ou représentant(e) autorisé(e) Date

Nom : ____________________
En lettres moulées s.v.p.

Titre/Poste : ____________________
En lettres moulées s.v.p.

Note: Please contact the National Office of Pollution Prevention for more information about electronic reporting or the filing of paper forms.

Schedule 3: Request for Time Extension – Inorganic Chloramines and Chlorinated Wastewater Effluents (Subsection 56(3) of CEPA 1999)

Notice Reference Code: P2CLMWWE

Please refer to the instruction booklet "Instructions for Completing the Schedules of the *Canada Gazette* Notice Requiring the Preparation and Implementation of Pollution Prevention Plans for Inorganic Chloramines and Chlorinated Wastewater Effluents" for guidance on how to complete this Request.

Electronic copies of the Notice, and the instructions for completing the declarations (Schedules 1 to 5), are available from the National Office of Pollution Prevention Web site at www.ec.gc.ca/nopp/p2p/en/p2notices.cfm or can be requested by telephone at (819) 994-0186, by facsimile at (819) 953-7970 or by e-mail at CEPAP2Plans@ec.gc.ca.

1.0 Information on the Person or Class of Persons Subject to the Notice

Name of the Person or Class of Persons Subject to the Notice: ______

Facility Name: ______

Street Address of Facility: ______

City: ______ Province/Territory: ______ Postal Code: ______

Telephone Number: (with area code) ______ E-mail (if available): ______

If different from Street Address
Mailing Address of Facility: ______

City: ______ Province/Territory: ______ Postal Code: ______

National Pollutant Release Inventory ID (if no ID, leave blank): ______

Six-digit North American Industry Classification System (NAICS) Code: 221320

Facility Technical Contact: ______

E-mail (if available): ______

Telephone Number: (with area code) ______ Fax Number (if available): (with area code) ______

2.0 Request for Time Extension

Identify for which of the following a time extension is requested (choose one):

☐ to prepare a pollution prevention plan

☐ to submit an Interim Progress Report — Interim Progress Report No. ______ ***(not applicable for this Notice)***

☐ to implement a pollution prevention plan

For the person(s) identified in Part 1.0, it is requested that the date be extended to ______ (specify exact date – year/month/day)

3.0 Rationale for Request

Explain why further time is necessary to prepare or implement a pollution prevention plan.

4.0 Certification

I hereby certify that the information provided in this Request is true, accurate and complete.

______ ______
Signature of the Person(s) Subject to the Notice or Duly Authorized Representative Date

Name: ______
Please Print

Title/Position: ______
Please Print

Schedule 4: Interim Progress Report – NOT APPLICABLE FOR THIS NOTICE

Note : Veuillez communiquer avec le Bureau national de la prévention de la pollution pour obtenir plus d'information au sujet de la soumission électronique ou du dépôt des formulaires écrits.

Annexe 3 : Demande de prorogation du délai — Chloramines inorganiques et eaux usées chlorées [paragraphe 56(3) de la LCPE (1999)]

Code de référence de l'avis : P2CLMWWE

Pour plus d'information sur la façon de remplir cette déclaration, veuillez consulter la brochure « Directives pour remplir les annexes de l'avis de la *Gazette du Canada* requérant l'élaboration et l'exécution de plans de prévention de la pollution pour les chloramines inorganiques et les eaux usées chlorées ».

Une copie électronique de cet avis et les instructions pour remplir les déclarations (annexes 1 à 5) sont disponibles sur le site Web du Bureau national de la prévention de la pollution à l'adresse www.ec.gc.ca/nopp/p2p/FR/p2notices.cfm ou peuvent être obtenues par téléphone au (819) 994-0186, par télécopieur au (819) 953-7970 ou par courriel à l'adresse cepap2plans@ec.gc.ca.

1.0 Renseignements sur la(les) personne(s) ou catégorie de personnes visée(s) par l'avis

Nom de la(des) personne(s) ou catégorie de personnes visée(s) par l'avis : ____________________

Nom de l'installation : ____________________

Adresse civique de l'installation : ____________________

Ville : ____________ Province/Territoire : ____________ Code postal : ____________

Téléphone : ____________ Courriel (si disponible) : ____________
(y compris l'indicatif régional)

Adresse postale de l'installation, si différente de l'adresse civique : ____________________

Ville : ____________ Province/Territoire : ____________ Code postal : ____________

Numéro d'identité de l'Inventaire national des rejets de polluants (si aucun, laissez en blanc) : ____________

Code à six chiffres du Système de classification des industries de l'Amérique du Nord (SCIAN) : 221320

Responsable des renseignements techniques : ____________________

Courriel (si disponible) : ____________________

Téléphone : ____________ Télécopieur (si disponible) : ____________
(y compris l'indicatif régional) (y compris l'indicatif régional)

2.0 Demande de prorogation du délai

Indiquez pour laquelle des raisons suivantes une prorogation du délai est demandée (cochez une case seulement) :

☐ pour l'élaboration du plan de prévention de la pollution

☐ pour la présentation d'un rapport provisoire — rapport provisoire n° ____________ ***(ne s'applique pas à cet avis)***

☐ pour l'exécution du plan de prévention de la pollution

Pour la(les) personne(s) désignée(s) dans la partie 1.0, il est demandé que le délai soit reporté au : ____________ (indiquez la date exacte — année/mois/jour).

3.0 Justification de la demande

Expliquez pourquoi une prorogation de délai est nécessaire pour élaborer ou mettre en œuvre le plan de prévention de la pollution.

4.0 Certification

Par la présente, j'atteste que l'information dans cette demande est véridique, exacte et complète.

____________________ ____________________
Signature de la(des) personne(s) visée(s) par l'avis ou représentant(e) autorisé(e) Date

Nom : ____________________
En lettres moulées s.v.p.

Titre/Poste : ____________________
En lettres moulées s.v.p.

Annexe 4 : Rapport d'étape provisoire — NE S'APPLIQUE PAS À CET AVIS

Note: Please contact the National Office of Pollution Prevention for more information about electronic reporting or the filing of paper forms.

Schedule 5: Declaration That a Pollution Prevention Plan Has Been Implemented – Inorganic Chloramines and Chlorinated Wastewater Effluents (Subsection 58(2) of CEPA 1999)

Notice Reference Code: P2CLMWWE

Please refer to the instruction booklet "Instructions for Completing the Schedules of the *Canada Gazette* Notice Requiring the Preparation and Implementation of Pollution Prevention Plans for Inorganic Chloramines and Chlorinated Wastewater Effluents" for guidance on how to complete this Declaration.

Electronic copies of the Notice, and the instructions for completing the declarations (Schedules 1 to 5), are available from the National Office of Pollution Prevention Web site at www.ec.gc.ca/nopp/p2p/en/p2notices.cfm or can be requested by telephone at (819) 994-0186, by facsimile at (819) 953-7970, or by e-mail at CEPAP2Plans@ec.gc.ca.

Is this an amendment to a Declaration previously submitted? ☐ Yes ☐ No

If yes, complete Parts 1.0 and 9.0 and any other Parts of this Declaration where previously reported information has become false or misleading. Previously reported information that is unchanged need not be resubmitted.

1.0 Information on the Person or Class of Persons Subject to the Notice

Name of the Person or Class of Persons Subject to the Notice: ____________

Facility Name: ____________

Street Address of Facility: ____________

City: ____________ Province/Territory: ____________ Postal Code: ____________

Telephone number: ____________ E-mail (if available): ____________
(with area code)

If different from Street Address
Mailing Address of Facility: ____________

City: ____________ Province/Territory: ____________ Postal Code: ____________

National Pollutant Release Inventory ID (if no ID, leave blank): ____________

Six-digit North American Industry Classification System (NAICS) Code: 221320

Facility Technical Contact: ____________

E-mail (if available): ____________

Telephone Number: ____________ Fax Number (if available): ____________
(with area code) (with area code)

2.0 No data are required for Part 2.0 of this Declaration

3.0 Substance and Activity

Substance and Activity for which information is required

Inorganic Chloramines and Chlorinated Wastewater Effluents: Persons identified in section 2 of the Notice who are required to prepare and implement a pollution prevention plan for inorganic chloramines and chlorinated wastewater effluents for the use of chlorine or chlorine compounds in wastewater systems and the release of chlorinated effluent to surface water.

4.0 Baseline Information after Implementation of the Pollution Prevention (P2) Plan

This Declaration requires reporting of data for the year of implementation (January 1 to December 31) of the pollution prevention plan, but no later than for the year 2009 (as specified in the Notice or any other year specified to a person who has been granted an extension of time to implement a plan).

Indicate the year of implementation for which the person(s) is(are) reporting: ____________ (This will be the Reporting Year throughout this Declaration.)

4.1 - 4.4 No information is required for Parts 4.1 to 4.4 of this Declaration

4.5 Additional Baseline Information

4.5.1 Wastewater System Information

Describe the changes to your wastewater system since **2004** or **2005**, compared to the information provided in Schedule 1: Declaration that a pollution prevention plan has been prepared and is being implemented.

4.5.2 Releases to Surface Water

4.5.2.1 Inorganic Chloramines and Chlorinated Wastewater Effluents

Report in the table below the average flow of wastewater effluent and the maximum Total Residual Chlorine (TRC) concentrations. The average monthly flow should be determined on the basis of daily flow measurements. The maximum total residual chlorine concentration should be determined on the basis of representative sampling.

Implementation Year ______ (Month)	Average Flow of Effluent (m^3/day)	Maximum Total Residual Chlorine (TRC) Concentration (mg/L as Cl^-)
January		
February		
March		
April		
May		
June		
July		
August		
September		
October		
November		
December		

5.0 Action(s) Taken and Results Achieved

5.1 Action(s) Taken

The following section (Parts 5.1.1 through 5.1.6) must be completed separately for ***each*** *action taken in the P2 plan, i.e. this section will be completed as many times as there are actions taken to report.*

In Part 5.1.1, describe, for the activity identified in Part 3.0 of this Declaration, the action taken in implementing the Pollution Prevention Plan. In Parts 5.1.2 and 5.1.3, identify whether the action represents pollution prevention method(s) or other environmental protection method(s) by selecting from the list of options provided below. In Part 5.1.4, report, where possible, the corresponding change to the maximum concentration of total residual chlorine measured in the effluent released to surface water achieved from implementation of that action, in mg/L. Refer to the instructions for specific information on how to report. Indicate a decrease with a negative sign ("–") and an increase with a positive sign ("+") in front of the reported change. Note that estimating a quantitative change for some actions taken, such as training, may not be possible. Finally, in Part 5.1.6, identify the completion date for each action taken.

5.1.1 Action Taken: ______________________________

5.1.2 Type of Pollution Prevention Method(s):

☐ Equipment or process modifications
☐ Spill and leak prevention
☐ On-site reuse, recycling or recovery
☐ Good operating practices or training
☐ Other: ______________________________

5.1.3 Other Type of Environmental Protection Method(s):

☐ Energy recovery
☐ Off-site recycling
☐ Waste treatment
☐ Pollution control
☐ Disposal
☐ Other: ______________________________

5.1.4 Results of Actions Taken in 5.1.1: ______________________________

5.1.5 No information is required for Part 5.1.5 of this Declaration

5.1.6 Completion Date (year/month/day): ______________________________

This ends the section (Parts 5.1.1 through 5.1.6) that must be completed separately for each action taken in the P2 plan.

5.2 No information is required for Part 5.2 of this Declaration

5.3 Detailed Results Achieved Information

Total Results Achieved for Inorganic Chloramines and Chlorinated Wastewater Effluents

The table below summarizes, for the activity identified in Part 3.0 of this Declaration, the achieved change to the maximum concentration of total residual chlorine (TRC) in the effluent released to surface water, in mg/L, and as a percentage relative to the preparation year.

Report the change achieved from all actions taken as a result of implementing the pollution prevention plan.

Maximum Concentration of TRC in the Preparation Year (mg/L)	**Achieved Maximum Concentration of TRC in the Implementation Year (mg/L)**	**Achieved change* in Maximum Concentration (%)**

* Indicate a decrease with a negative sign ("−") and an increase with a positive sign ("+") in front of the reported change.

6.0 Monitoring and Reporting

For the activity identified in Part 3.0 of this Declaration, describe the monitoring and reporting used to track progress in implementing the Pollution Prevention Plan.

7.0 Risk Management Objective

For the activity identified in Part 3.0 of this Declaration, describe how the Pollution Prevention Plan outlined in this Declaration met the risk management objective identified in subsection 4(3) of the Notice. If this plan did not meet the risk management objective, explain why.

8.0 No information is required for Part 8.0 of this Declaration

9.0 Certification

I hereby certify that a pollution prevention plan has been implemented for inorganic chloramines and chlorinated wastewater effluents and that the information provided in this Declaration is true, accurate and complete.

Signature of the Person(s) Subject to the Notice or Duly Authorized Representative

Date

Name: ____________________
Please Print

Title/Position: ____________________
Please Print

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Note : Veuillez communiquer avec le Bureau national de la prévention de la pollution pour obtenir plus d'information au sujet de la soumission électronique ou du dépôt des formulaires écrits.

Annexe 5 : Déclaration confirmant l'exécution d'un plan de prévention de la pollution — Chloramines inorganiques et eaux usées chlorées [paragraphe 58(2) de la LCPE (1999)]

Code de référence de l'avis : **P2CLMWWE**

Pour plus d'information sur la façon de remplir cette déclaration, consulter la brochure « Directives pour remplir les annexes de l'avis de la *Gazette du Canada* requérant l'élaboration et l'exécution de plans de prévention de la pollution pour les chloramines inorganiques et les eaux usées chlorées ».

Une copie électronique de cet avis et les instructions pour remplir les déclarations (annexes 1 à 5) sont disponibles sur le site Web du Bureau national de la prévention de la pollution à l'adresse www.ec.gc.ca/nopp/p2p/FR/p2notices.cfm ou peuvent être obtenues par téléphone au (819) 994-0186, par télécopieur au (819) 953-7970, ou par courriel à l'adresse cepap2plans@ec.gc.ca.

La présente déclaration apporte-t-elle une modification à une déclaration déjà présentée? ☐ Oui ☐ Non

Si vous avez coché « oui », remplissez les parties 1.0 et 9.0, et toute autre partie de cette déclaration pour laquelle des renseignements déjà déclarés sont maintenant faux ou trompeurs. Il n'est pas nécessaire de soumettre les informations inchangées se trouvant dans des déclarations précédentes.

1.0 Renseignements sur la(les) personne(s) ou catégorie de personnes visée(s) par l'avis

Nom de la(des) personne(s) ou catégorie de personnes visée(s) par l'avis : ____________________

Nom de l'installation : ____________________

Adresse civique de l'installation : ____________________

Ville : ____________ Province/Territoire : ____________ Code postal : ____________

Téléphone : ____________________ Courriel (si disponible) : ____________________
(y compris l'indicatif régional)

Adresse postale de l'installation, si différente de l'adresse civique : ____________________

Ville : ____________ Province/Territoire : ____________ Code postal : ____________

Numéro d'identité de l'Inventaire national des rejets de polluants (si aucun, laissez en blanc) : ____________

Code à six chiffres du Système de classification des industries de l'Amérique du Nord (SCIAN) : 221320

Responsable des renseignements techniques : ____________________

Courriel (si disponible) : ____________________

Téléphone : ____________________ Télécopieur (si disponible) : ____________________
(y compris l'indicatif régional) (y compris l'indicatif régional)

2.0 Il n'est pas nécessaire de fournir de données pour la partie 2.0 de cette déclaration

3.0 Substance et activité

Substance et activité pour lesquels certaines informations sont requises

Chloramines inorganiques et eaux usées chlorées : Personnes identifiées dans l'article 2 de l'avis, qui doivent élaborer et exécuter un plan de prévention de la pollution pour les chloramines inorganiques et les eaux usées chlorées liées à l'usage du chlore ou de composés chlorés dans les réseaux d'assainissement et le rejet d'eaux usées chlorées dans les eaux de surface.

4.0 Information de base suivant l'exécution du plan de prévention de la pollution (P2)

*Cette déclaration requiert la présentation des données pour l'année d'exécution (du 1er janvier au 31 décembre) du plan de prévention de la pollution, qui se trouve au plus tard pour l'année **2009** (tel qu'il est précisé dans l'avis, ou toute autre année spécifiée à une personne qui a obtenu une prorogation du délai pour l'exécution d'un plan).*

Indiquez l'année d'exécution pour laquelle la(les) personne(s) doit(doivent) soumettre son(leur) rapport : ____________ (Cette nouvelle année sera considérée comme l'année pour laquelle le rapport doit être fait, aux fins de cette déclaration.)

4.1 - 4.4 Aucune information n'est requise pour les parties 4.1 à 4.4 de cette déclaration

4.5 Information de base additionnelle

4.5.1 Information sur le réseau d'assainissement

Décrivez les changements à votre réseau d'assainissement depuis **2004** ou **2005**, en comparaison à l'information fournie à l'annexe 1 : Déclaration confirmant qu'un plan de prévention de la pollution a été élaboré et qu'il est en cours d'exécution.

4.5.2 Rejets dans un plan d'eau de surface

4.5.2.1 Chloramines inorganiques et eaux usées chlorées

Déclarez dans le tableau ci-dessous le débit moyen de l'effluent d'eaux usées et les concentrations maximales de chlore résiduel total (CRT). Le débit moyen mensuel devrait être calculé en fonction des mesures du débit quotidien. La concentration maximale de chlore résiduel total devrait être déterminée en fonction d'un échantillon représentatif.

Année d'exécution ______ **(mois)**	**Débit moyen de l'effluent (m^3/jour)**	**Concentration maximale de chlore résiduel total (CRT) (mg/L en Cl⁻)**
Janvier		
Février		
Mars		
Avril		
Mai		
Juin		
Juillet		
Août		
Septembre		
Octobre		
Novembre		
Décembre		

5.0 Mesure(s) mise(s) en œuvre et résultat(s) obtenu(s)

5.1 *Mesure(s) mise(s) en œuvre*

Les parties suivantes de la présente déclaration (parties 5.1.1 à 5.1.6) doivent être remplies séparément pour ***chaque*** *mesure prévue indiquée dans le plan de prévention de la pollution, c'est-à-dire que cette section doit être remplie autant de fois qu'il y a de mesures à déclarer.*

Dans la partie 5.1.1, décrivez pour l'activité identifiée à la partie 3.0 de la présente déclaration la mesure mise en œuvre pour exécuter le plan de prévention de la pollution. Dans les parties 5.1.2 et 5.1.3, indiquez si cette mesure représente une mesure de prévention de la pollution ou toute autre mesure de protection de l'environnement, en choisissant l'une des options fournies ci-dessous. Dans la partie 5.1.4, inscrivez, le cas échéant, le changement à la concentration maximale de chlore résiduel total mesuré dans l'effluent rejeté à l'eau de surface, en mg/L, résultant de la mise en œuvre de la mesure. Pour obtenir des informations spécifiques sur la façon de compléter cette section, référez-vous aux instructions. Indiquez une diminution par le signe « – » et une augmentation par le signe « + » devant la quantité indiquée. Notez que dans certains cas il peut s'avérer impossible d'estimer un changement quantitatif pour certaines mesures mises en œuvre, par exemple la formation du personnel. Enfin, dans la partie 5.1.6, indiquez la date d'achèvement prévue pour chaque mesure prévue.

5.1.1 Mesure mise en œuvre : ______________________________

5.1.2 Types de méthodes de prévention de la pollution :

☐ Modifications de l'équipement ou du procédé
☐ Prévention des fuites ou des déversements
☐ Récupération, réutilisation ou recyclage sur place
☐ Bonnes pratiques d'exploitation ou formation
☐ Autres : ______________________________

5.1.3 Autres types de méthodes de protection de l'environnement :

☐ Récupération d'énergie
☐ Recyclage hors site
☐ Traitement des déchets
☐ Contrôle de la pollution
☐ Élimination
☐ Autres : ______________________________

5.1.4 Résultats des mesures mises en œuvre en 5.1.1 : ______________________________

5.1.5 Aucune information n'est requise pour la partie 5.1.5 de cette déclaration

5.1.6 Date d'achèvement (année/mois/jour) : ______________________________

Ici se termine la section (parties 5.1.1 à 5.1.6) devant être remplie séparément pour chaque mesure mise en œuvre dans le plan de prévention de la pollution.

5.2 *Aucune information n'est requise pour la partie 5.2 de cette déclaration*

5.3 Information détaillée sur les résultats obtenus

Résultats totaux obtenus pour les chloramines inorganiques et les eaux usées chlorées

Le tableau ci-dessous résume, pour l'activité identifiée dans la partie 3.0 de cette déclaration, le changement obtenu à la concentration maximale du chlore résiduel total (CRT) dans l'effluent rejeté dans l'eau de surface, en mg/L, et en pourcentage par rapport à l'année de préparation.

Déclarez le changement obtenu à la suite de toutes les mesures mises en œuvre découlant de l'exécution du plan de prévention de la pollution.

Concentration maximale de CRT dans l'année de préparation (mg/L)	**Concentration maximale de CRT atteinte dans l'année de la mise en œuvre (mg/L)**	**Changement* obtenu à la concentration maximale (%)**

* Indiquez une diminution avec un signe négatif (« – ») et une augmentation avec un signe positif (« + ») devant la quantité déclarée.

6.0 Surveillance et rapport

Pour l'activité identifiée à la partie 3.0 de cette déclaration, décrivez les méthodes de surveillance et de compte rendu utilisées pour suivre les progrès de l'exécution du plan de prévention de la pollution.

7.0 Objectif de gestion du risque

Pour l'activité identifiée à la partie 3.0 de cette déclaration, décrivez comment le plan de prévention de la pollution, tel qu'il est décrit dans cette déclaration, a répondu à l'objectif de gestion du risque décrit au paragraphe 4(3) de l'avis. Si ce plan n'a pas répondu à l'objectif de gestion du risque, expliquez pourquoi.

8.0 Aucune information n'est requise pour la partie 8.0 de cette déclaration

9.0 Certification

J'atteste qu'un plan de prévention de la pollution a été exécuté pour les chloramines inorganiques et les eaux usées chlorées et que les renseignements soumis dans la présente déclaration sont véridiques, exacts et complets.

____ ____

Signature de la(des) personne(s) visée(s) par l'avis
ou représentant(e) autorisé(e)

Date

Nom : ____

En lettres moulées s.v.p.

Titre/Poste : ____

En lettres moulées s.v.p.

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